# AVIATION MEDICINE

## ITS THEORY AND APPLICATION

BY

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## PILOT'S ECSTASY

Oh! I have slipped the surly bonds of earth,
  And danced the skies on laughter-silvered wings,
Sunward I've climbed, and joined the tumbling mirth
  Of sun-split clouds—and done a hundred things

. . . . . . . . . . . . . . . . . . . .

The high, untrespassed sanctity of space,
  Put out my hand, and touched the hand of God

*Anon*

# PREFACE

THIS work does not claim to be a treatise of original research, and it would be presumptuous for the author to claim any credit for the work described That honour is due to the many specialists in various fields who have from time to time published their findings Rather it is an attempt to present to the medical profession, in readable and compact form, a brief review of the physiological, medical, psychological, and epidemiological problems associated with aviation in its various aspects

For reasons of brevity and conciseness, such a work, presenting as it does an outline only, of the subjects covered, cannot convey to the reader an adequate description of the great volume of detailed research involved, for which information other specialized publications should be consulted, references have been provided to aid readers in this respect

Every endeavour has been made to ensure accuracy of the subject-matter presented, by submitting the text of various chapters to acknowledged experts in the respective spheres concerned, and to whom due acknowledgment is made below. As a result, it will be apparent that some statements are expressions of personal opinion, and the book eclectic rather than dogmatic It has been written in a private and unofficial capacity only, and should not, therefore, be regarded as the authorized opinion of any particular body or organization

From the time of the original work of Paul Bert in 1870, the results of whose findings have been so conclusively vindicated in recent years, until to-day, there has been a steady flow of research on the many stresses to which the human frame is subject when man forsakes terrestrial transportation for aerial The advent of the first and second world wars added enormous impetus to these investigations, which to-day are being conducted at a more peaceful *tempo* Such research is carried out by a variety of workers First, the scientist whose task is to investigate and report on the theoretical problems submitted, secondly, the research worker who has to translate and apply such findings to the practical solution of flying questions as they are presented, and last but not least, aircrew medical officers and flying personnel themselves, who are faced with the actual problems and their solution under flying conditions.

All have a valuable contribution to make, and it is by harmonious co-ordination and integration of such knowledge and experience that progress in knowledge of flying conditions, methods of meeting problems, and programmes for future research are achieved There is no doubt that the safety factor in flying is very closely allied to satisfactory operating conditions for flying personnel, and such conditions have been greatly influenced as a result of medical and scientific research in the past. The problems of the future are no less complex, but there is no reason why their solution cannot be met in the same way Technical advances in aircraft design, construction, and performance are useless if conditions in aircraft are inimical to life or efficient performance of aircrew duties. Research on the two aspects must go hand in hand. Much work has been accomplished, much still remains to be done

My acknowledgements and grateful thanks are due to many authors, publishers, authorities, and individuals who have allowed me to use material, both written and illustrative, in this work, including among others the following The Controller, His Majesty's Stationery Office, The Director of Naval Intelligence, Admiralty, The Director-General of Medical Services, Royal Air Force, The Director of Medical Services, British Overseas Airways Corporation, The Director, Royal Canadian Air Force School of Aviation Medicine, The Director, Wellcome Research Institute, London, The Chairman, Personnel Licensing Division, International Civil Aviation Organization, and, also, Air Marshal Sir H E Whittingham, K C.B., K B E, LL.D, F.R C P., F.R C S, F R.F P S, D P H, D T.M & H., B H. C Matthews, Esq, C B E, M.A, Sc D., F R S.; W. R Franks, Esq., M D, C W Flemming, Esq, O.B E, M Ch, F R C.S., K W Donald, Esq, D S C, M D, M R C.P; The Oxford University Press, Messrs J B Lippincott Co., London; Headley Brothers, London, Baillière, Tindall & Cox, London; Spencer (Banbury) Ltd, England; Saunders-Roe Ltd, Cowes, The Bristol Aeroplane Co., Ltd, A. V Roe & Co, Ltd, Manchester, Martin-Baker Aircraft Ltd, Denham, Parke, Davis & Co, Ltd., London, The British Overseas Airways Corporation; *The British Medical Journal*; *The Lancet*, *The Practitioner*; *The Journal of Oto-rhino-laryngology*, *The Journal of Aviation Medicine*, *The Aeroplane*; *Flight*; The McGraw-Hill Publishing Co, New York, The Williams & Wilkins Co, Baltimore, U S A.; Pan-American Airways System, The Aero Medical Research Laboratory, Wright Field, U.S A, The Mayo Clinic, Rochester, Minnesota, U S A; The Bruce Publishing Co, Illinois, U S.A, The Berger Brother Co, U S A; The Air-research Manufacturing

has been obtained from *Human Factors in Air Transport Design*, by Ross A. McFarland, Ph D , *Principles and Practice of Aviation Medicine*, by H G Armstrong, M D , F A C P , *Aviation Medicine*,

*Air Force*, by H E Whittingham , *Contributions to Aviation Otolaryngology*, by E D. D Dickson and others ; *The Medical Examination for Fitness for Royal Air Force and Civil Flying* (Air Publication, No 130, H M S O , 1941) , *Psychological Disorders in Flying Personnel of the Royal Air Force investigated during the War* 1939–45 (Air Publication, No 3139, H M S O , 1947) , *The Physiology of Flight*, by the Staff of the Aero Medical Research Laboratory, Wright Field, Dayton, Ohio, U S A , *Global Epidemiology*, by J S Simmons, M D , T F Whayne, M.D , G W Anderson, M D , and H M Horack, M D , *The Story of the 'G' Suit*, by Maj -General D N W Grant , and a number of publications of the Medical Directorate of the Royal Air Force (Crown copyright reserved) Where not referred to directly in the text, such assistance is gratefully acknowledged now Imitation is the sincerest form of flattery, and where it is considered that the description given in a text cannot be bettered, it is given in unaltered form. The use which has been made of the work of many authors should be regarded as a mark of appreciation for all that has been learned from them

I am also greatly indebted to many long-suffering aircrew with whom I was privileged to work during the war and subsequently, who from time to time subjected themselves willingly, albeit critically, to experiment and trial Their comments and suggestions were invariably constructive and helpful

I would also like to express my appreciation to those experts in their respective fields who have read sections of the manuscript, and as a result of whose advice and criticism the text has emerged in its present form , particularly Air Marshal P C. Livingston, C B , C B E , A F C , F R C S , R A F , Air Commodore E D D Dickson, C B E , F R C S , D L O , R A F , Air Commodore J C Neely, D M , D O , D.O.M S , R A F , Air Commodore J Kyle, M R C S , L R C P , R A F , Brigadier J S K Boyd, O B E , M.D , D P H ; Squadron Leader H L Roxburgh, M B , B Ch., B Sc., Ph D , R A F , Squadron Leader A W H Oakey, F R San I., F I.S E., R A.F , Flight

Lieutenant J Bazarnik, M.B., B Ch, R A F.; Denis Williams, Esq, M D, D Sc, F.R C P.; J. Tillisch, Esq, M D.; W. R. Lovelace, jun, Esq, M D.; R. H. Barrett, Esq, M.R C.S., L R C P, D P H, D.T.M. & H; J E. Gabb, Esq, B.A., M R C S, L R C P., T F. Macrae, Esq., D.Sc., D. F. Gibbs, Esq., B Sc.; and Mrs E Gwilt, D.B O.

In the psychological section the nomenclature used, and methods of investigation described, are largely based on those recommended by Sir Charles P Symonds, K B E, C.B, M.D., F.R C P., and Dr D J Williams in their *wartime reports on psychological* problems associated with aircrew personnel in the Royal Air Force, and more recently issued as an official Air Ministry publication. The findings reached by them form the substance of this section, together with personal observations, aided by the views of other independent observers, both lay and professional.

It would be more than ungracious not to refer here to the unfailing forbearance, skilled advice, and meticulous attention to detail, of the publishers, Messrs John Wright & Sons Ltd, whose great helpfulness at all times has been much appreciated, and to whom the greatest credit is due for the excellent quality of the finished product, irrespective of the merits of the subject-matter

Lastly, I would like to acknowledge the willing efforts of those without whose energy, patience, and enthusiasm the manuscript of this book would not have been written I would particularly like to mention Miss M Storie, Miss J Blane, and Miss J Whitelaw in this connexion To these and others, who in various ways have been of help, I am most grateful, and offer my sincere thanks.

It should be stressed that a work of this sort can never claim to be completely up to date, as while it is being written new ground is being covered, old theories are being discarded, new ideas are being born, for this reason some of the facts and figures given can, and do, only represent current opinion Examples of this are the standards of medical fitness for aircrew laid down by the International Civil Aviation Organization (I.C.A O), many of which will be modified in the light of experience The same uncertainty applies to existing inoculation and vaccination procedures It is hoped to remedy such defects by revision of subsequent editions, so that readers may be brought into line with current research, development, and opinion in all aspects of aviation medicine

Statistical Tables, I C.A O Physical Standards, Epidemiological Maps, approved International Inoculation Forms, and other relevant data are provided in Appendixes

*June*, 1949 K. G BERGIN

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# FOREWORD

By Air Vice-Marshal Sir William Tyrrell,
K.B.E., D.S.O., M.C., LL.D., M.B., B.Ch., D.P.H.

It is with peculiar interest, not only in the matter presented, but also in the author, that I have read this instructive book on Aviation Medicine. The progressive development of all forms of flying, and in particular air passenger transport, demands the parallel study, research, and co-ordinated practical application of many allied subjects, including aerodynamics, aeronautical design, all forms of propulsion, aircraft structure and layout, and, last but not least, that on which all finally depends—the human factor.

It is incumbent upon all air services to establish and maintain a consistent reputation for safety, regularity, and comfort in air travel, based on effectively co-ordinated executive and medical supervision. This will ensure, not only physically fit and mentally alert aircrews and ground personnel, but will also co-ordinate parallel investigation and attention to the medical and human aspects of aircraft design, structure, layout, and performance.

This humanization of air transport services involves every aspect of medical science, combining the practical application and implementation of what is known, with research into what has yet to be learned. Although aviation medicine is a comparatively recent branch of medicine as a whole, it has attracted to its study and application many eminent scientists and research workers, and, as a result, a large volume of literature and information has been presented on the subject from time to time. The collection of the essentials of this accumulated but scattered knowledge into one compact and readable volume, suitable for presentation to those members of the medical profession unacquainted with the problems associated with flying, presents many difficulties. If too much detail is included, the book becomes cumbrous; if too little, readers complain it is sketchy. The happy medium is not easy of attainment.

Dr. Bergin has brought to this task high professional, technical, and personal qualifications, including his wide experience as a qualified pilot of many years' standing in both civil and military flying, and medical officer in charge of operational aircrew personnel in the Royal Air Force. From this background he has compiled a comprehensive review of the many aspects of aviation medicine.

W. TYRRELL

# PART I INTRODUCTION

# AVIATION MEDICINE

## CHAPTER I

## THE DEVELOPMENT OF AVIATION MEDICINE

THE tremendous strides made in all forms of aviation in recent years have led to a complete reconsideration of existing views, a new approach to the problems encountered, and new lines of research, related to travel in heavier-than-air machines

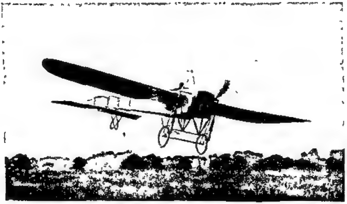

*Fig 1 — Aircraft of the Past* The monoplane in which Blériot flew the Channel in 1911, powered by a 50-h p Gnome engine (*By courtesy of 'Flight'*)

At one time the limitations imposed upon flying were those of the internal combustion engine, the torsional strength of an aircraft frame, or other mechanical considerations This is no longer so Current developments in all forms of mechanical propulsion, and the recent innovation of jet and rocket power units have added further problems for consideration It is apparent that the future performance of aircraft will be limited, not only by mechanical factors, but also by the ability of the human organism to stand up to the stresses imposed upon it, or, what is even more important,

the ability of designers so to construct aircraft that living conditions within them are not related to their actual position in, or progress through, the atmosphere, but conform with conditions at, or near, *ground level*, for this reason the study of the physiological, psychological, and medical aspects of flying are of great importance to the future of aviation, and indirectly to mankind as a whole.

The recent advances in all forms of aviation, particularly emphasized in the struggle for air supremacy in the recent war, while

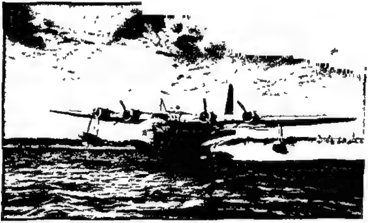

*Fig 2—Aircraft of the Present—Civil* Short 'Plymouth' Flying Boat This flying boat operates over Empire routes, range 2400 miles, weight approximately 30 tons powered by four 1200-h p Pratt and Whitney piston engines, carries 22 passengers and 7 crew at 220 m p h (*By courtesy of British Overseas Airways Corporation*)

only touching on the fringe of what may be expected in the not too distant future, have given a clear indication of some of the fundamental problems which are going to be met with, and which are discussed in the following pages.

It is generally conceded that flying, as far as man is concerned, ... century, with the exception of the mythical ... however, that ... smoke-filled balloon in France, subsequently descending safely, and it was to be nearly eighty years later that the first scientific observations in flight were made, when Glaisher and Coxwell made a balloon ...

ten miles an hour in a train. A few ... 1903, the famous

Wright brothers made the first heavier-than-air flight, which was to mark the beginning of an epoch distinguished by revolutionary and spectacular advances in all forms of scientific research and development on the ground and in the air, and which to-day has assumed such vital importance in the most recent convulsion in which mankind has been involved

As was to be expected, all early incursions into the subject of flying were attended by the disapproval of theologians, the doubt of scientists, and the mistrust of the general public, as had always

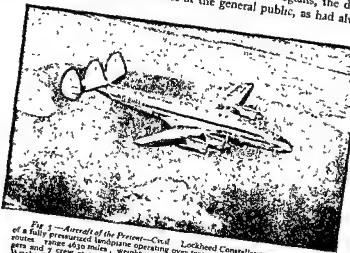

*Fig 3*—*Aircraft of the Present*—*Civil* Lockheed Constellation An example of a fully pressurized landplane operating over trans-continental and trans-oceanic routes range 4630 miles, weight approximately 50 tons carries over 50 passengers and 7 crew at a cruising speed of 330 m p h Powered by four 2500-h.p Wright Cyclone piston engines An aircraft of this type fully loaded will maintain a height of 8000 ft on two engines only The crew and passenger cabins are fully pressurized (*By courtesy of British Overseas Airways Corporation*)

been the case in anything new or unknown, and it was confidently stated that, although man had apparently conquered the earlier problems of heavier-than-air flight, the limitations of the human organism would preclude any great advancement or utilization of flying to the extent which we see to-day.

In 1911 the world was startled by the first cross-Channel flight by Bleriot (*Fig* 1), soon after that the advent of the first World War, acting, as wars do, as a stimulus to progressive scientific development, accelerated all forms of investigation, production, and research, and work proceeded at a greatly increased *tempo* By 1918 it was recognized that the heavier-than-air machine had potentialities then unexplored. The concomitant advance in design of the internal combustion engine was a great factor in the

progress made, because reliability and efficiency of propulsion were the most important factors necessary to satisfactory development.

In the years intervening between the two wars the internal combustion engine made enormous strides in power-weight ratios, reliability, and versatility. Speeds reached, weights carried, distances covered, and heights attained, all broke existing records with monotonous regularity year after year. With the advent of

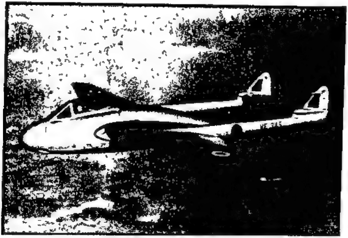

*Fig 4.—Aircraft of the Present—Military* De Havilland 'Vampire' single-seat fighter at present in use in the Royal Air Force Powered by one De Havilland 'Goblin' turbo-jet engine giving 3000 lb thrust at 10,200 r p m Maximum level speed at sea level, 531 m p h Fully pressurized pilot's cabin (*By courtesy of 'Flight'*)

jet propulsion, turbo-compression units, and more lately rocket-propulsion, trans-sonic speeds and other similar advances in performance can confidently be expected

In *Figs* 2–7 are illustrated some of the present and future types of aircraft, from which it will be seen that progress has been very considerable since the early days Even more remarkable changes can be expected in the future

With the onset of the Second World War the subject of aviation medicine immediately assumed greatly increased significance, but before this the Royal Air Force, anticipating the need of specialized research into such matters, had approved the establishment of an Institute of Aviation Medicine to deal with research into the physiological, medical, and psychological aspects of flying. This was located at an R.A.F. airfield where aerodynamic and other research was being conducted, thus ensuring that problems relating

to aviation medicine were investigated hand in hand with the most recent scientific advances in aircraft design, structure, and performance. Similar institutions conducted parallel research in other countries, such as the United States Navy's School of Aviation Medicine at Pensacola, Florida; the United States Army Air Force School of Aviation Medicine, Randolph Field, Texas; the

*Fig 5.—Aircraft of the Present—Military* Gloster 'Meteor' single-seat fighter at present in use in the Royal Air Force. Powered by two Rolls-Royce Derwent turbo-jet engines giving a speed of 585 m p h at sea-level and a service ceiling of 54 000 ft. Rate of climb at sea-level 7500 ft per minute. Fully pressurized cabin. (*By courtesy of 'Flight'.*)

Mayo Clinic, Rochester, Minnesota, the Royal Canadian Air Force Institute of Aviation Medicine, Toronto, Ontario, and many other research centres in America and elsewhere. Subsequent evidence has shown that similar research was going on in Germany and other countries at the same time. In all these institutions many of the doctors concerned with research were themselves qualified pilots of considerable experience. Basically the idea was to have a physiological and medical research centre manned by doctors and scientists in immediate contact with flying problems as they were presented. From the outset these institutions proved of immense value to the flying services in dealing with such questions during the course of the war, and while the advent of peace has resulted in a lessening of their urgency, civil aviation presents its

full quota of problems, quite apart from the military questions which still arise.

In addition to these establishments there was formed in England early in 1940, with the authority of His Majesty's Secretary of State for Air, a body of distinguished scientists and doctors, known as the Flying Personnel Research Committee, whose object was to initiate research on problems of this nature, and to make recommendations to the authorities on findings submitted as a result of investigations. The work done by this Committee and the reports and recommendations they made were of the greatest value, and subsequently the scope of its activities was enlarged to cover problems of civil as well as military aviation, many of which are closely allied and cover the same field of inquiry.

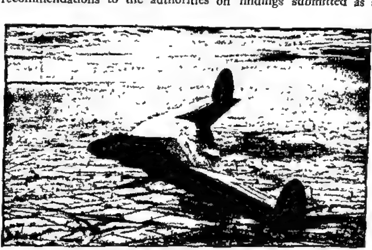

*Fig 6.—Aircraft of the Present—Experimental* Armstrong-Whitworth A.W. 52 all-metal experimental tailless monoplane, powered by two Rolls-Royce 'Nene' turbo-jet engines, giving 10,000 lb static thrust Fully pressurized cabin (*By courtesy of 'Flight'*)

The value of medical supervision of aircrew and aviation medical research is now widely accepted, and the provision of a department for dealing with all medical matters affecting aircrew personnel, whether on the ground or in the air, medical aspects of aircraft design, layout, and construction, and psychological problems associated with flying, including psychiatric examinations, pre-selection tests, and extrinsic factors affecting aircrew performance, is recognized as being of great importance. In addition to these problems there are questions of medical standards for aircrew and their assessment, methods of conducting such examinations, and many other physiological problems associated with flying.

To-day there exists an Aero-Medical Association with a world-wide membership of over three thousand professional men, a number which gives some idea of the interest shown in this subject now that air travel has been developed to such a high degree

It is true to say that England is in no way behind, and in many cases is in advance of, other countries in this branch of scientific research, and in the following chapters an attempt is made to present to the reader some of the problems which arise, and the

methods adopted to meet them in the light of present knowledge and experience Certain detail has been omitted, as it is the intention of the author that this volume shall present in readable form an outline of the subjects considered, full appraisal of which would fill many text-books

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# Part II PHYSIOLOGICAL CONSIDERATIONS

## *CHAPTER II*

# THE ATMOSPHERE AND RESPIRATION

## I. THE ATMOSPHERE

When considering medical problems in connexion with aviation, it is essential that certain basic fundamentals concerning changes of atmospheric pressure should be known. Prior to the days of aviation, human physiology was confined to problems associated with terrestrial conditions, and in such problems of altitude as were encountered in mountaineering, the heights concerned were relatively limited, the occasions few and far between, and adequate time was allowed for human acclimatization, due to the method of ascent employed. To-day, when aircraft can reach 30,000–40,000 ft. and more in a few minutes, the profound changes in atmospheric conditions which the body encounters must be modified if life is to be maintained.

For practical purposes to-day, the upper limits of aviation may be considered as round about 50,000 ft., although with the present rapid advances in aircraft design, this may soon be superseded. All medical problems are increased in the upper limits of the atmosphere, and it is anticipated that they will not diminish as greater heights and speeds are reached. Under present operational conditions aircraft services are limited to the troposphere, and it is not expected that aircraft will operate at the higher level or stratosphere for some time yet, although this has undoubted advantages, such as diminished turbulence, smaller variations in temperature, and absence of moisture. *Figs.* 8, 9, and *Tables I* and *II* illustrate the physical variables of the atmosphere, from which will be observed the variations in pressure and temperature which exist at different heights. It will be seen that at sea-level, atmospheric pressure is 760 mm. Hg or 14.6 lb./sq. in.; at 20,000 ft. it is 349 mm. Hg or 7 lb./sq. in., and at 40,000 ft. 141 mm. Hg

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with increasing altitude

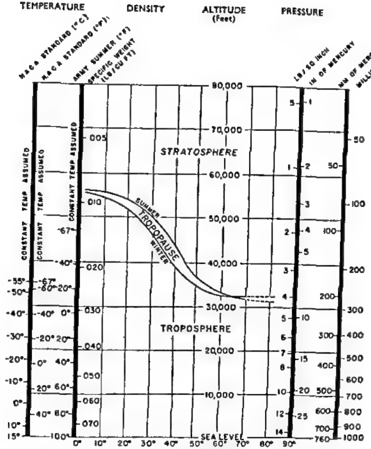



*Fig* 8—Atmosphere chart (*By courtesy of Airesearch Manufacturing Co*)

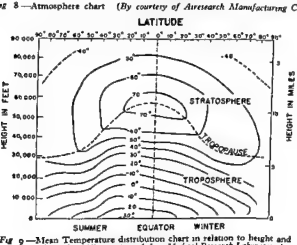



*Fig* 9—Mean Temperature distribution chart in relation to height and latitude (*By courtesy of Aero Medical Research Laboratory*)

oxygen saturation of the blood during ascent, breathing atmospheric air and oxygen respectively. As the partial pressure of the oxygen decreases, the hæmoglobin becomes less and less oxygenated, as shown in *Fig.* 12, and as a result the tissues are

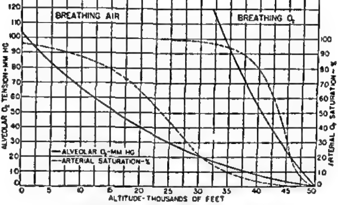



*Fig* 11.—Percentage oxygen saturation of arterial blood breathing oxygen and air

denuded of necessary oxygen. From this it will be seen that no improvement is obtained by the breathing of pure oxygen.

There are, however, compensatory mechanisms which come into play. First, the reduction in oxygen stimulates the respiratory centre

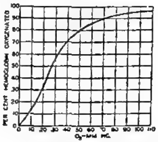



*Fig* 12.—Oxygen dissociation curve of arterial blood

in the medulla, which produces hyperventilation of the lungs. ... ty of carbon ... Secondly, ... creases, and there is a temporary increase in pulse-rate and blood-pressure. The pulse pressure is at first raised, but later returns to normal. The precise reason for this return to normality is not clear.

Thirdly, the phenomenon known as the Bohr effect comes into play, whereby, if the carbon dioxide of the blood is reduced below normal levels the hæmoglobin assumes a greater affinity for oxygen, and in consequence a greater saturation with oxygen is possible

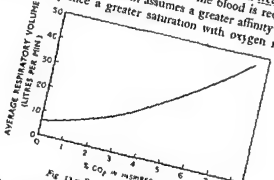



Fig 13.—Effect of $CO_2$ on respiration

Coincident with this, however, there is a greater retentive power for oxygen in the blood, with the result that it is not liberated to the tissues, which thereby suffer from anoxia. The Bohr effect can of course work either way. Another factor which has to be

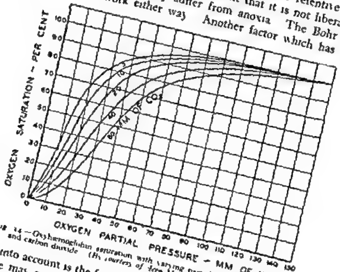



Fig 14.—Oxyhæmoglobin saturation with varying partial pressures of oxygen and carbon dioxide (By courtesy of Aero Medical Research Laboratory.)

ken into account is the fact that although the variations of carbon oxide may not produce much effect on the oxygen dissociation ve at sea levels, at high altitudes, when the blood is not fully urated with oxygen, variations in carbon dioxide may produce

relatively

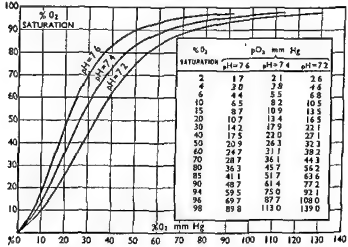
globin

different

in *Fig* 14

carbon dioxide content. Varying oxygen dissociation curves with different *p*H's of the blood are shown in *Fig.* 15

Experiments conducted with slow ascents to height, as, for example, mountaineering expeditions to Everest and other notable peaks, have shown that in cases of this sort, provided the ascent




| % $O_2$ SATURATION | $pO_2$ mm Hg pH=7 6 | pH=7 4 | pH=7 2 |
|---|---|---|---|
| 2 | 1 7 | 2 1 | 2 6 |
| 4 | 3 0 | 3 8 | 4 6 |
| 6 | 4 4 | 5 5 | 6 8 |
| 10 | 6 5 | 8 2 | 10 5 |
| 15 | 8 7 | 10 9 | 13 5 |
| 20 | 10 7 | 13 4 | 16 5 |
| 30 | 14 2 | 17 9 | 22 1 |
| 40 | 17 5 | 22 0 | 27 1 |
| 50 | 20 9 | 26 3 | 32 3 |
| 60 | 24 7 | 31 1 | 38 2 |
| 70 | 28 7 | 36 1 | 44 3 |
| 80 | 36 3 | 45 7 | 56 2 |
| 85 | 41 1 | 51 7 | 63 6 |
| 90 | 48 7 | 61 4 | 77 2 |
| 94 | 59 5 | 75 0 | 92 1 |
| 96 | 69 7 | 87 7 | 108 0 |
| 98 | 89 8 | 113 0 | 139 0 |

*Fig* 15 —Oxygen dissociation curves for human blood at various *p*H levels

is over a long period of time, such as several weeks, the following physiological compensations take place (Matthews) —

*a* The red blood-corpuscle count rises by as much as 50 per cent, and the oxygen-combining capacity of the blood is thereby increased (*Fig* 16)

*b* The ventilation-rate progressively increases, the *resulting* alkalosis being compensated by excretion of base. The acclimatized person is, therefore, enabled to breathe rapidly with a normal *p*H of the blood.

*c*. There are changes in the tissue oxidase system, which enable the cells to work normally in spite of the reduced oxygen pressure in the blood reaching them. In animals the concentration of myoglobin in the diaphragm is approximately doubled with acclimatization

A reversal of these processes takes place about a fortnight after returning to sea level.

At heights over 18,000 ft little or no further acclimatization appears to take place, and over 20,000 ft a marked deterioration in physical condition may be observed Personnel sleep badly, lose weight, and are capricious in their diet This latter may be attri-

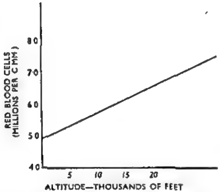



*Fig* 16 —Increase in numbers of R B C.s with height

These factors do not apply to the problem we are considering, but are mentioned in passing as being of interest in having a bearing on the problem from a purely physiological angle It has been shown that in intermittent exposure to altitudes of 10,000–14,000 ft, as not infrequently occurs in pilots not using oxygen, a decrease in the red blood-cell count occurs. However, as will readily be understood, the degree of altitude tolerance depends largely on the rate of climb This is shown in *Table III*.

*Table III*—The Effect of Rate of Climb on Altitude Tolerance
(*Average of* 50 *Animals*)

| Rate of Climb | Altitude Tolerance |
|---|---|
| ft /min | ft |
| 100 | 30,915 |
| 1,000 | 37,235 |
| 5,000 | 39,045 |
| 10,000 | 40,300 |
| 30,000 | 45,175 |

(*After Armstrong, 'Principles and Practice of Aviation Medicine'*)

lack can be clearly seen At high altitudes stimulation of breathing by oxygen lack tends to increase the excretion of carbon dioxide, which in turn inhibits breathing, the result of this is irregular breathing of the Cheyne-Stokes type. Furthermore, the discharge of carbon dioxide disturbs the regulation of muscular tone, which is manifested by a tendency to weakness and fainting at high altitudes Breathing is so regulated that the partial pressure of carbon dioxide in the alveolar air is kept as close to normality as

important facts may be observed on inspection of the oxygen dissociation curve (*Fig* 12, p 18):—

*a.* Alveolar oxygen pressures above 100 mm Hg produce only

average alveolar oxygen pressure is about 70 mm. Hg

The pressure of carbon dioxide in alveolar air is almost identical with its pressure in venous blood, and the same is true of oxygen pressures when the blood is less than 93 per cent saturated with oxygen At higher arterial saturations alveolar oxygen partial pressure tends to be higher than arterial oxygen partial pressure. This is thought to be due to a decreased rate of combination of oxygen and hæmoglobin as saturation is approached, so that the time that the blood remains in the capillaries is not sufficient to produce complete equilibrium between alveolar oxygen and the blood.

**2. Oxygen Requirements at Altitude.**—There are many variables which have to be considered when an attempt is made to maintain sea level conditions in the lungs by the addition of oxygen to the inspired air The first of these is obviously the altitude reached, but, as has been mentioned previously, the percentage of oxygen required at height is not directly proportional to the atmospheric pressure on account of the presence of a constant partial pressure of water vapour and carbon dioxide in the lungs The percentage of oxygen required in inspired air if the correct alveolar oxygen tension is to be maintained is indicated in *Fig.* 17 and *Table IV* Another consideration is the amount of exercise taken. There are great differences between the oxygen requirements of a person at rest, such as a passenger, one engaged in a

sedentary task such as that of navigator, wireless operator, or pilot, and one engaged in active physical exercise, such as a steward.

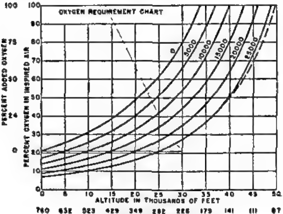



*Fig* 17—Percentage oxygen requirements for maintaining sea-level alveolar oxygen pressures (*From 'Keeping Fit for Flying', by courtesy of Pan-American Airways System*)

*Table IV*—Percentage of Pure Oxygen which must be mixed with Each Breath to Maintain Alveolar Oxygen Pressure at 100 mm Hg

| Altitude | Added Oxygen |
|---|---|
| ft (thousands) | Per cent |
| 10 | 13 |
| 15 | 22 |
| 20 | 34 |
| 25 | 51 |
| 30 | 75 |
| 34 | 100 |

(*After Armstrong*)

Boothby, Bulbulian, and Lovelace, using a closed-circuit apparatus, have drawn up a scale of oxygen requirements for inactive and very active aviators, the latter category including persons engaged in the most strenuous exercise that could be expected in aircraft operations The variation in oxygen requirements under such circumstances is shown in *Table V*

Other workers, using similar, though not identical, apparatus, have recorded similar oxygen requirements at varying heights, but the figures are largely dependent on the type of circuit being used If it is a free-flow open circuit the oxygen flow will be the same, irrespective of whether inspiration or expiration is taking place.

This is obviously much more wasteful than a system in which the oxygen flow automatically ceases during expiration. The action of the economizer is described in greater detail in a subsequent section.

*Table V*—RATES OF OXYGEN FLOW REQUIRED AT VARIOUS ELEVATIONS WITH DIFFERENT DEGREES OF ACTIVITY

*Closed Circuit*

| ACTUAL ELEVATION | AVIATOR INACTIVE | AVIATOR VERY ACTIVE |
|---|---|---|
| ft (thousands) | l/min S P T D | l/min S P T D |
| 0 to 10 | 0.5 | 1.0 |
| 11 to 15 | 0.7 | 1.4 |
| 16 to 20 | 1.0 | 1.8 |
| 21 to 25 | 1.3 | 2.2 |
| 26 to 30 | 1.7 | 2.6 |
| 31 to 35 | 2.1 | 2.9 |
| 36 to 40 | 2.4 | Dangerous |

(*After Lovelace*)

Extracts from experimental figures using an open free-flow circuit indicate greatly increased oxygen requirements with increasing heights, as shown below.

| *Height* ft (thousands) | *Oxygen Requirements* l/min S P T D |
|---|---|
| 15 | 3.9–7.7 |
| 25 | 7.5–15.1 |

The efficiency of the apparatus used, and freedom from leaks, are important factors in determining the amount of oxygen actually consumed by the user; the amount of oxygen leaving the reservoirs is not necessarily a criterion of what is being inhaled from the mask. Such items as correct fit of mask, leak-free joints, and properly controlled valves are important in this respect.

In addition to oxygen requirements for normal persons, other variables include the presence of organic disease, particularly of the respiratory, cardiovascular, or hæmatopoietic system, under which circumstances oxygen requirements will be increased. Fear and apprehension also increase oxygen requirements, and the needs of a highly-strung or neurotic individual will be greater than those of the majority of air travellers

From the above figures it is apparent that the number of variable factors which operate in determining oxygen requirements necessitate a wide margin of safety being employed When calculating oxygen requirements under the circumstances described, the flow is calibrated in litres per minute at standard density, temperature, and pressure, the gas being dry (S.T.P.D.).

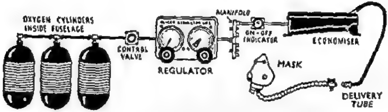



*Fig. 18* —Layout of typical oxygen system in aircraft Diagrammatic.

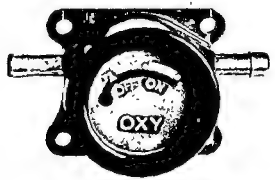



*Fig* 19 —Oxygen flowmeter

(*Figs* 19–22 *Royal Air Force crown copyright reserved*)

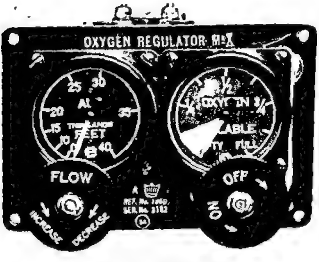
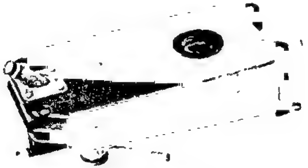
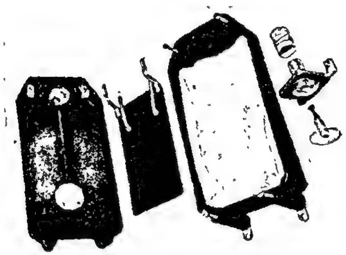



*Fig* 20 —Oxygen regulator

of air and oxygen appropriate to the altitude. The advantage of this type of regulator is that the supply of oxygen is in accord with the user's needs. Disadvantages include manufacturing difficulties in that it is a complicated piece of apparatus, and secondly,





Figs. 21, 22.—Economizer unit.

the necessity of a well-fitting mask at all times. It is not extensively used for passengers in aircraft.

*b The Economizer System.*—The amount of oxygen delivered by this apparatus is controlled, either individually or centrally, within

ger, and accumulates there during expiration. On inspiration it is delivered to the mask. As at low altitudes only a small amount of oxygen is used, a spring-loaded air-entry valve is provided in the mask, which is so arranged that the valve opens when the economizer has been emptied. This system has the disadvantage that no additional oxygen is provided under conditions of work or exercise, but it is simple, reliable, and safe. *In this case mask-leakage must be* reduced as far as possible, but is not so dangerous or wasteful as is the case with the demand valve.

*c The Rebreather System.*—This system is also based on a continuous flow of oxygen delivered to each person. The amount is controlled as in the previous system The continuous flow is led to a collapsible bag attached to the mask by a wide-bore tube. During expiration the bag is filled with both incoming oxygen and exhaled air. On inspiration the bag is emptied. No valves are used, and expiration is through a network of small holes in the mask The system is the same as that used in the B.L.B. mask which is familiar to clinicians, and, associated with a cheap light-weight plastic mask, lends itself very well to passenger use. It is, however, dangerous if low temperatures are to be encountered. An example of the economy which can be effected by means of reservoir types of apparatus is shown in *Table VI.*

*Table VI*—SCALES OF OXYGEN SUPPLY FOR TRUE AND RESERVOIR DELIVERIES

| ALTITUDE | OXYGEN REQUIREMENTS IN LITRES (N T.P ) PER MAN PER MINUTE | |
|---|---|---|
| *ft* | True Delivery | Reservoir Delivery |
| 10,000 | 2 | 1 0 |
| 15,000 | 3 | 1 5 |
| 20,000 | 4 | 2 0 |
| 25,000 | 5 | 2 5 |
| 30,000 | 7 | 3 5 |
| 35,000 | 8 | 4 0 |
| 40,000 | 9 | 4 5 |

**3. Masks.**—Oxygen is supplied to individual users by means of masks worn on the face, the precise design of which varies according to the requirements. Thus a military mask, or one for use by operational aircrews, being a personal issue to the aircrew member concerned, will be durable in nature and of robust construction, and will incorporate in the design such equipment as a microphone

Fig 23 —Selection of lightweight disposable oxygen masks for passenger use

Figs 24 25 —Service mask in position for use Note microphone for intercommunication

for intercommunication, with a heater to prevent the latter from freezing These masks are made in various sizes, and are equipped with non-return valves to separate expired gas from that entering. Oxygen enters high up in the mask so that the risk of freezing of the incoming supply is minimal. The expiration valves are carefully shrouded, so that in cold conditions their temperature is kept as high as possible, and freezing prevented. Those used by passengers, on the other hand, will be of a light construction and of pleasing æsthetic appearance, liable to cause the least worry and discomfort to the wearer Many types of light passenger masks have been designed, and the present trend is for a small, light plastic mask of poly-vinyl-chloride which fits over the nose and mouth and is kept in position by an elastic band which slips over the head It is desirable that all masks should possess the following features —

*a*. It should be a good fit on the face to prevent leakage of oxygen For this purpose several sizes should be available for use.

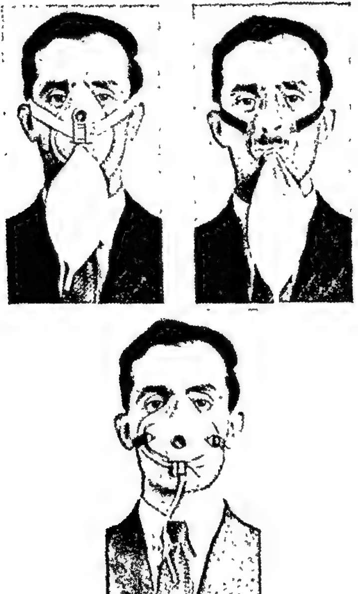
*b*. Adequate arrangements should be provided for the drainage of moisture of condensation.

*c*. The rebreather bag should be very light and not interfere with the wearer's freedom of movement

It is very important that the mask should be easily dismantled for cleaning and sterilization on æsthetic and hygienic considerations alone It is desirable that masks for passenger use should be expendable so that each passenger may be issued with an individual mask for personal use which can be thrown away afterwards and thus any risk of transference of infection, or of unhygienic conditions, be avoided In this connexion cost of manufacture is an important consideration, but with modern methods of construction it is not anticipated that this will be an insuperable difficulty. Various types of masks as described are illustrated in *Figs*. 23–28.

### *B* PORTABLE APPARATUS

There are several occasions when a portable apparatus is required In military service it is necessary when a member of the aircrew is called upon to *move about the aircraft in the course of his duties* It is also required when a person has to escape from an aircraft by parachute at great heights, when oxygen will be required until such times as descent is made to safe oxygen height. In civilian aircraft it may be needed by a steward or air hostess when *carrying out duties* in connexion with passengers, it may be necessary for passengers requiring to move about the aircraft; or, lastly, it may be required in the case of invalid passengers suffering from anoxia or who require oxygen at lower altitudes than normal,



Figs. 26-28. Different types of civilian masks in position for use. These masks, besides being easy to clean, aim at inconveniencing the wearer as little as possible.

on which occasions it may be a life-saving measure. Two systems are used for this purpose. The first is a simplification of the fixed apparatus and consists of a small portable cylinder carried in a container which can be strapped to the user, as illustrated in *Figs.* 29–31. Varying types are in use and a typical one of recent design weighs 4 lb, has a capacity of 120 l. of oxygen, and

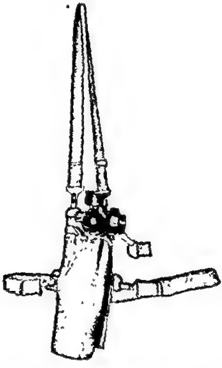


*Fig.* 29.—Portable oxygen cylinder, complete in carrying case with strap to go over shoulder

delivers at a rate of 2 l./min. S.T.P.D. for 60 minutes. Weight, endurance, and rate of flow are interchangeable factors which can be varied according to the requirements of the user.

Another type, at present in the stage of development, is that of an oxygen generator which consists of a candle of potassium tetroxide, or potassium or sodium chlorate, fired electrically or pyrotechnically. The tetroxide candle has the disadvantage of being much more liable to fire risk. Oxygen production in such instances is 99·7 per cent pure, and contains 0·3 to 0·4 per cent

carbon dioxide. Incorporated in the circuit is a filter to remove chloride from the gas generated A side-product of this chemical reaction involved is carbon monoxide and precautions against such an undesirable feature must be watched

*Fig* 30—Portable oxygen cylinder out of case

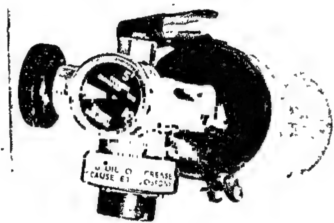


*Fig* 31—Details of regulator valve and supply gauge

Such a system if properly developed should, without difficulty, be able to produce oxygen at a rate of 2½ to 3 l /min. for one hour, and the whole apparatus should not weigh more than 4 lb This system is more economical in actual volume of oxygen than the reservoir system, as approximately 13 cu ft of generated oxygen is equivalent to 36 cu. ft of oxygen in reservoirs Furthermore, as the state of charge in an oxygen reservoir is reduced, the

*pressure is accordingly reduced* and the last few litres in any bottle have therefore to be discounted, as shown in the following table.

| *State of Charge* | *Pressure* lb/sq in |
|---|---|
| Full | 1800 |
| ¾ | 1350 |
| ½ | 900 |
| ¼ | 450 |

One of the disadvantages of portable apparatus is that a closed-circuit system is employed for reasons of economy of oxygen. This means that apparatus must be devised for dealing with the carbon dioxide in expired air. This can be achieved by the insertion in the circuit of some chemical such as soda-lime to absorb the carbon dioxide This is effective but adds to the weight and bulk of the apparatus At most altitudes small quantities of carbon dioxide in the inspired air are an advantage.

### C OXYGEN SUPPLIES FOR INFANTS AND VERY YOUNG CHILDREN

A mask is not a suitable method of providing oxygen to infants in arms and very young children, as the normal type of mask is unsuitable for this class of passenger, and several alternatives present themselves. A satisfactory method for relatively short trips is that of a soft conical rubber funnel similar to that used in anæsthetic apparatus, but *it has the disadvantage that it has to be held in place* by the mother or attendant. If, as is not unlikely, the mother falls asleep, the supply to the infant would be cut off, and the child might succumb in a short time.

An alternative arrangement is a type of relatively airtight box designed in the form of a 'carry-cot' in which oxygen is supplied under low pressure A portable one with transparent plastic top and sides has recently been devised which gives promising results in this respect, care must be taken that when opened for feeding and attention unexpected draughts do not lower the oxygen content to dangerous levels, or that when *the container is closed* the carbon dioxide concentration does not become too great. Further problems encountered in the experimental stage were those of excessive humidity in the container, and, secondly, rise in temperature of the subject, but both of these can be avoided by the exercise of suitable care and supervision, and methods of [illegible] problems are in the process of development.

child can be constantly watched, and the cot provides a useful light-weight *container in* which the child can sleep, [illegible] carried and fed.

### *D* PRESSURE BREATHING AND PRESSURIZED SUITS

This is a highly-specialized individual method of supplying *oxygen at heights greater than 33,000 ft and is applicable only in* certain cases It is described in detail elsewhere (Chapter X)

### *E* PRESSURE CABINS

The problem of oxygen supplies for high-flying aircraft is increasingly being solved by the use of pressurization equipment which stimulates conditions of atmospheric pressure at ground *level in the aircraft cabin at all altitudes,* thus *rendering individual* oxygen supplies unnecessary. The scale of oxygen requirements

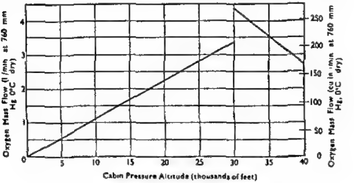



*Fig* 32 —Minimum oxygen requirements at various altitudes with pressurized cabins

in such cases is shown in *Fig*. 32 Pressurization is described in another chapter (Chapter X)

### *F* COMMENTS AND CONCLUSIONS

In a majority of airlines the use of oxygen in non-pressurized aircraft is compulsory above 10,000 ft and from the ground up for fast-climbing aircraft, or aircrew at night, the rulings given being dependent upon the circumstances under which they are called upon to operate Between 7000 and 15,000 ft. there is no grave danger to life if oxygen is not used, but experience has shown that not only is a man less mentally alert if he does not

development a compromise has in many cases to be effected

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# CHAPTER III

## VISION

### INTRODUCTION

No doubt *Arms and the Man* aptly described the fighting man of former days, but in controlling the complex machines of aerial warfare in modern times, *Eyes and the Man* is more appropriate. Of all the factors which contribute to efficiency and safety in the air, vision is probably the most important. Without it man cannot fly. It is the one thing he uses at all times, whether flying by night or day, on instruments or by external observation; on landing, on take-off, and in the air

The keen eyesight required by the fighter pilot in wartime is no less necessary for the peace-time aircrew member; now, as then, he must be prepared to assess every situation which might be rendered hazardous but for constant vigilance; his eyes must be answered instantly by the reflex action of the correct motor response, subconsciously transmitted by a brain trained and exercised in flying experience.

The automatic pilot may in some degree ease the strain imposed on the captain of a large aircraft, flying over long stretches of ocean, or in bad weather conditions, but the necessity for every pilot to check with his own eyes each take-off and landing still remains; particularly in such situations as pertain at any busy airport or harbour, where floating or mobile obstructions may intrude themselves, at the last moment in the line of flight. A pilot's vision, in its broader sense, does not mean his visual acuity alone, but embraces the whole sphere of visuo-cortical impressions which result from monocular and binocular vision. Judgements of distance, speed, and depth are made and maintained by training and constant practice, nevertheless, it remains true that many men with no demonstrable ocular abnormalities on the ground, display an inability to interpret and respond correctly to varying visual impressions in the air

A great deal of research has been undertaken and much time has been spent in attempting to assess the relative importance of visual acuity, night vision, colour vision, ocular muscle balance,

stereoscopic vision, and monocular and binocular aids in flying, but when all has been said there still remain those individuals who can overcome a physical disability and fly better than their fellows, to the confusion of experts and scientists alike

## VISUAL STANDARDS

[illegible] ation is necessary [illegible] ual interpretation [illegible] al standards for [illegible] They are given in detail in Appendix A

The fact that a pilot with only one eye, defective colour vision, or a high degree of ocular muscle imbalance may have several hundred flying hours to his credit, does not render his rejection by a commercial aviation company the less reasonable The risk of a restricted visual field, or the wrong interpretation of a coloured signal may be slight in the pilot's own estimation, but when men without these disabilities are available for flying duties, it is obvious that a high degree of physical excellence should be insisted upon, especially at the outset of a flying career Similarly, as regards ocular muscle balance; while it is undoubted, and has indeed been proved in practice, that many men with a high degree of latent strabismus can fly with safety, it has been shown in numerous cases in the late war, that some forms of heterophoria increase with *anoxæmia, fatigue, anxiety, or physical debility, until a time comes*

instruments, particularly after a long flight, another of constant headache, yet another of transient diplopia which is as confusing as it is dangerous. It is, therefore, desirable in the interests of safety, that when the assessment of a man for a flying career is made, a certain standard should be demanded, not only in his visual acuity, and in the amount of hypermetropia which he has constantly to overcome, but also in the angle of deviation which the axis of one resting or dissociated eye makes with its fellow, when this eye is focused, either for near or distant vision Such an explanation is apposite in view of the criticism to which the ocular standards of the Royal Air Force, and civil airlines in this country, have been subjected by ophthalmologists in different parts of the world

In Canada, for example, it has been shown, what has been known since the 1914–18 war and the days of Hinchcliffe, Wiley Post, and others, that in the appreciation of height and distance,

monocular aids, such as parallax and relative size, are sufficient for daylight flying With compensated heterophoria no difficulties present themselves and trained observers have flown with the axes of their eyes rendered divergent by the artificial use of a prism placed base inwards before the master eye Similarly, experienced lawn-tennis players have found no difficulty in hitting with their accustomed accuracy a tennis ball served hard when holding a three dioptre prism held base inwards before one eye. (A tennis ball served thus has been estimated to travel at approximately 100 m p h.) Numerous other cases may be cited of men who have had successful careers in athletics and aviation in spite of ocular disadvantages which, on theoretical grounds, might well have been considered insuperable Many examples could be given, ranging from monocular pilots, to the rare condition of complete absence of stereoscopic vision which is sometimes found with binocular vision. Although the testing of stereoscopic vision by means of percentage charts may not give absolute results, it is clear that the speed with which the candidates can appreciate the positional differences between the component figures, as well as the degree of stereoscopic vision, varies considerably.

The faculty of fine stereoscopic judgement based on the appreciation of disparate retinal points is often undeveloped and many pilots rely almost entirely on the coarser aids such as perspective, relative size, and parallax

Fixed standards of stereoscopic vision have not been adopted in England, since there appears to be little correlation between stereoscopic vision and flying ability. Stereopsis, like the fixation reflex, appears to be of greater importance in acting as a tie-rod in the movements of synergic ocular muscles, and in maintaining normal compensation in a naturally occurring phoria For this reason the development of stereoscopic vision is undertaken *pari passu* with the elimination of suppression and the strengthening of duction power in the training of a symptom producing heterophoria

Manifest hypermetropia should not exceed plus 2·25 dioptres sphere in either eye without the use of a mydriatic Hypermetropia in excess of this is liable to cause disturbances in accommodation and visual judgement, especially after fatigue and the strain of tropical service The occurrence of presbyopia will further diminish visual acuity, especially at near range

Myopia should disqualify even when visual acuity is within acceptable limits, if the candidate is still growing, and if recent changes in the strength of his spectacles has been necessary, or if there is evident abnormality of the optic disk, characteristic of

active myopia In astigmatism there must not be a greater ( than $\pm$ 2 5 D cyl

Depth perception is the ability to appreciate or discriminate third dimension, to judge distance, and to orientate onesel relation to other objects within the visual field It is of ( importance in aviation, because by this means pilots are ena to perform the complicated task of coming in to land, or the jud of relative distances in the air, and many manœuvres assoc with flying Many factors are concerned with depth perceptio which the more important are the following

Estimation of the size of the retinal image is important pilots with uniocular vision require it more than those binocular vision. Motion parallax is also of value in this conne It is similar to binocular parallax but differs from it in that former depends on motion of the observer or the object b observed. Terrestrial association and aerial perspective are acquired characteristics developed through training, experi and association of ideas In both cases light, reflections, shad linear perspective, and overlapping contours are all utilized, a constantly replenished reservoir of visual impressions go make up the photographic impression by which a pilot ju terrestrial form from the air, or when approaching the gro Another factor in depth perception is the ability to reco differences in distance between two objects within the visual by reason of the fact that any object in the visual field at a dist other than the object fixed, gives rise to diplopia Bino parallax is also important, and is the impression of shape, r or solidity given to an object by the slightly different images duced on the retina by reason of the fact that the right eye a little more of the right side of the image and vice versa. ( factors such as fatigue, anoxia, alcohol, and other extrinsic fa all diminish the powers of depth perception These factor discussed more fully in other sections

## THE INFLUENCE OF INHERITANCE ON OCUL CONDITIONS

Before describing the different tests employed in the c examination of an aircrew candidate, it would be wise to say s thing of heredity in its relationship to ocular conditions and c natural means which are employed in attempting to overcom more common optical defects

Inheritance plays a large part in the development not of the eyeball itself but also in its physiological imperfec

Squint, cataract, glaucoma, colour defects, night blindness, as
as many optical errors, nystagmus, and certain forms of co
*and retinal degeneration, comprise some of the many form*
ocular conditions which can be transmitted either by domi
or recessive inheritance. From the point of view of eugenics
the prevention of disease, it seems to be a matter of vital import
that not only doctors, but all responsible citizens, should
informed on the subject of good or diseased inheritance.

Apart from actual disease, the size and shape of the eyeba
inherited, and in the majority of cases accounts for many of
commoner optical errors met with in adolescence. The na
attempts made to overcome these defects and to improve v
acuity are often used to the limit of endurance by exponent
the "perfect sight without glasses" creed. As in many me
nostrums there is an underlying element of truth in this content
*and many enthusiastic candidates have paid big fees to have t*
eyesight strengthened by natural means, in order to enable t
to reach the visual standard required for flying. An interes
example of this was the case of a man who had been treated by
osteopath and, assured of a cure, had journeyed all the way f
New Zealand in order to join the Royal Air Force. When
eyes were examined, it was found that without screwing them
he could see no more than the largest letters of the test ty
although when he narrowed the palpebral aperture by squeez
his lids together he could read several lines more. The bone
his neck which had been shown to him on an X-ray plate,
which had been held responsible for pressing on the optic ne
and interfering with its electrical processes, was the odont
*process of the atlas situated in its natural position.*

## REFRACTIVE ERRORS

Brc

1.

2.

3.

*In hypermetropia the antero-posterior diameter of the eye*
shortened in the majority of cases, but provided the subject
young, and the error is not beyond the accommodative power
the lens, he can compensate for the shortened eyeball by the const
use of his ciliary muscle. In testing the vision for distance in
young hypermetrope no diminution in visual acuity will be foun
but the 6/6 line can still be seen through convex lenses of increasi
strength. The measure of manifest hypermetropia is given by t
highest dioptre sphere through which he can read 6/6.

On the other hand, owing to the depletion in power of the ciliary muscle, caused by the need for constant focusing even for distant objects, the near point will be found to be farther away than in the normal of the same age

Conversely, myopic subjects can see at close range with the minimum use of accommodation, but they cannot of course see clearly at a distance Having an eye which is too long in its antero-posterior diameter, they cannot flatten their own lens sufficiently for clear vision and the only means open to them is either to screw up their eyes until they are looking through a self-made stenopæic slit or to wear concave glasses to render the parallel rays of light divergent. It is also frequently possible in astigmatism to eliminate some of the rays which form the diffusion image on the retina by narrowing the palpebral aperture It is by these methods, and by the mental education necessary for the interpretation of blurred visual impressions, that claimants for the cure of defective vision without glasses are able to achieve their so-called successful results.

## VISUAL ACUITY

Visual acuity is the ability of the eye to appreciate form, and the usual method by which visual acuity is measured is by utilizing the visual angle; that is, the angle formed at the nodal point of the eye by the intersection of two rays proceeding from the extremities of the object being viewed to the retina

The two points can be seen as separate and distinct entities when the visual angle formed by the crossing of the two axial rays is a minimum of one minute

Visual acuity is measured by means of a series of optotypes of Landholt, Snellen's test types, or similar non-serif optotypes, illuminated by not less than 12 lux, and not more than 20 lux placed at a distance of 20 ft. (6 metres) from the candidate. Each test type is so formed that at a given distance from the eye each stroke of the letter subtends an angle of one minute, and the letter as a whole, an angle of five minutes

A minimum standard of visual acuity of 6/18 in each eye separately without correction is required in civil flying, and 6/9 by the Royal Air Force

Correction may be achieved by the use of corrective goggles, spectacles, or contact lenses The stenopæic disk is used to determine correctibility. If it is not correctible by this means, the candidate should not be passed

Visual acuity may be influenced by a variety of factors Thus, owing to the subject's familiarity with the objects viewed, he may

be able to give a more exact interpretation would warrant Furthermore, he may, by co himself to recognize objects which otherwise to do.

In the examination it is important to adop cautions —

1. Ensure that the eye which is not being covered.

2 Ensure that the test type is clean and pr at the proper distance of 20 ft from the patient, a series is presented for each eye.

3 Observe the candidate carefully so that he d his eyes, even momentarily, to obtain a clearer vi

## VOCATIONAL ASPECTS OF VIS FUNCTION

Vocational examinations and aptitude tests are as aviation as they are in industry From the medical is of importance to be able to estimate the candidat for a particular occupation as well as his general physic In most modern factories an ophthalmological exa undertaken in order to assess ocular fitness for a kind of work In America, the worker's so-called prof available in order to assist in placing him in a suitabl It is reasonable, therefore, in the ocular examination of are to make a career of aviation, that the occupational flying upon the visual apparatus should be considered itself is an extensive subject, but without entering into t detail the following aspects must be taken into consider order to obtain a comprehensive assessment of a can suitability for flying duties.

1 The influence of anoxæmia, particularly with regard cumulative effect of long flights near the borderline limit of pensatory physiology

2 Low barometric pressure.

3 The effect of light, of the longer and shorter wave-leng glare, wind, and extremes of heat and cold

4 The indirect effects of fatigue and debility, both mental a physical

5. Diet, both in its relation to vitamins and germ-free food of proper nutri the various

6 The possible toxic effects associated with flying, such as those caused by carbon monoxide, fumes from petrol, oil, or other waste gases

7 Prophylaxis in regard to the correction of optical errors, the provision of tinted glasses, and experience with contact lenses, as well as the prevention of the effects which may be caused under the foregoing headings

## THE EFFECT OF PHYSIOLOGICAL VARIABLES ON VISION

The visual apparatus cannot be considered apart from the general physiology of aviation Still less can the eye be considered from the point of view of optics alone, to be dealt with as a camera divorced from central connexions, and metabolic activities Particularly is this true in relation to anoxæmia and low barometric pressure Thus the sensitivity of night vision to the effects of oxygen want, retarded cerebration, altered *p*H of the blood, fatigue, and sensory stimulation must always be taken into account Similarly the liberation of gas bubbles may take place at high altitude, both in the vessels of the peripheral visual cells and in those supplying the higher cortical connexions

Under anoxæmic conditions the vessels of the retina dilate and at simulated altitudes of 18,000–21,000 ft a dilatation of 10–20 per cent has been noted Work carried out by many workers on the cerebral vessels suggests that similar changes occur Mercier and Duguet think that the dilatation of retinal vessels forms an important circulatory test of adaptation In the perimacular region the increase in volume and the development of collateral vessels account in all probability for the preservation of central vision

Wilmer and Berens found that visual acuity is not affected at altitude Observations made in the low-pressure chamber at the Royal Air Force Institute of Aviation Medicine show that visual acuity remained practically unchanged in spite of the marked effect of anoxæmia on the higher centres at 22,000 ft Similarly, colour sense and stereoscopic appreciation are not affected adversely at altitude, provided cerebration and lighting conditions remain adequate

Many observers have obtained slightly variable results in their investigations on peripheral vision As McFarland points out, the explanation probably lies in the waning power of concentration, and in the weaker response of the retina to the low illumination at altitude.

Broadly speaking, the fields of vision even at heights above 22,000 ft remain, to all intents and purposes, unchanged. Halstead, however, has drawn attention to the cumulative effect of even small degrees of anoxæmia upon the visual fields, when diurnally experienced for four to six weeks At the end of the third or fourth week there was a progressive increase in the number of mistakes made on the perimeter These were not corrected by the inhalation of pure oxygen and in some cases persisted on the ground for some days or even weeks Subjectively, this evidence is corroborated by the *experience of pilots engaged in such occupations* as daily meteorological flights One of these, at the beginning of his tour of duty, stated that he never took oxygen After he had *been flying daily for about three months, however, at a height of* 10,000–12,000 ft he confessed he felt the need for oxygen, and subsequently took it regularly during his flights

*It should be noted that in this case the pilot was young,* which probably accounts for the length of time that he was able to compensate partially for the oxygen deficiency. It is doubly important, *therefore, that all crews flying regularly at this height should be* aware of the physiological need for additional oxygen

## ACCOMMODATION

One of the reasons why hypermetropes of over 2·25 D S. are not accepted for a flying career is the effect that anoxæmia has upon the power of accommodation. Pilots themselves have found that focusing on their instruments for long hours becomes increasingly difficult, until it is often impossible to see the panel clearly for more than a few seconds at a time Since the end of the 1914–18 war many investigations have been carried out in this connexion, when it has been found that the near point of accommodation recedes on an average 3 cm. during ascent to 18,000 ft The methods of examination are too subjective, however, for precise figures to be given, especially when the higher cortical centres begin to be affected by the anoxæmia

## OCULAR MUSCLE BALANCE

ent e
bet 1
ocular muscle balance; perfect ocular muscle balance or orthophoria is rarely encountered.

Heterotropia, or manifest deviation from the visual line, is easily observed, usually as a convergent or divergent squint.

Heterophoria or latent squint, an imbalance, or tendency towards deviation of the two visual lines from parallel is not uncommon, but is not usually recognizable without further examination It may be subdivided into the following types —

1 Exophoria or external latent squint is the one most commonly found.

2. Esophoria or internal latent squint; frequently associated with hypermetropia

3 Hyperphoria and hypophoria, latent upward and downward deviations which are comparatively rare

4 Cyclophoria, a rare state in which images in the two eyes are tilted at an angle to one another, resulting in the suppression of one owing to the impossibility of proper fusion.

A considerable volume of literature has been written about this subject, particularly in its relationship to depth perception and to the accurate handling of aircraft near the ground Bad landings, instead of being attributed to lack of practice or care, to fright, fatigue, exhibitionism, bombast, or simple over-confidence, have often found refuge and excuse in the state of the ocular muscles

It was formerly taught that exophorics tend to flatten out their aircraft too early, having judged the ground to be nearer than it actually is; conversely esophorics are inclined to fly into the ground. In point of fact this contention cannot be supported in practice, and Elliott found no correlation between the landing errors of 175 student pilots and exo- or esophoria

It would be somewhat unnatural to expect that, when learning to land, a pilot should continue to repeat his mistake and make no effort to compensate, or even to over-compensate, for an initial error of judgement It therefore appears to be unreasonable to expect that a man who, because of an ocular muscle imbalance, should theoretically fly into the ground, would actually do so Conceivably this might be the case were he to fly solo without any previous instruction, in spite of the fact that the majority of pilots during their training tend to hold off too high rather than bring their aircraft down to the correct height from the ground, before they check their glide, or later, their angle of approach The purpose of a medical examination, however, is to say not merely that a candidate who, for example, has a low blood pressure [illegible]

known to be likely to deteriorate further under the influence of increasing age, alcohol, debility, or fatigue, is not judged to be incapable of learning to fly, but to be less suitable for a flying career

than a candidate who is not suffering to the same degree from such defects

The most commonly used tests for heterophoria are as follows :—

**1. Maddox Rod.**—*The latent deviation of the eyes from the* normal relative position may be assessed by this test. The Maddox rod consists of a red glass lens with parallel horizontal ridges. If placed before the eye when looking at a point source of light, this latter is refracted in such a way that the point appears as a streak at right angles to the long axis of the rod. The candidate, wearing a single or multiple trial frame (*Fig.* 33), is seated 20 ft from a

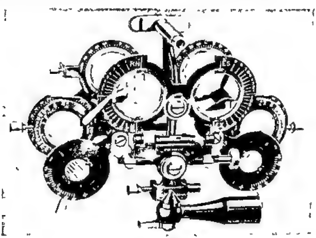

*Fig* 33 —Phorometer

spotlight, other sources of light in the room being excluded as far as possible. The Maddox rod is placed in one eyepiece of the frame, the other eye being left uncovered With the cylinders of the rod placed horizontally, a vertical line of light is seen by one eye, while the uncovered eye sees the spotlight. The position of the line relative to the spotlight is noted. If, for example, the Maddox rod is in front of the right eye and the line of light is seen to the left of the spotlight, exophoria is present Conversely, in esophoria the line of light is seen to the right of the spotlight. By placing the cylinders of the rod vertically in the trial frame, a horizontal line is seen by the candidate, and hyperphoria can be detected The amount of deviation is assessed by the strength of the prism required to bring the line of light over the spotlight

**2. Maddox Rod at 33 cm.**—The estimation of the degree of heterophoria for near vision can be measured by means of this

test If the reading shows an exophoria of more than 10, or an esophoria greater than 6, then an assessment of the dynamic muscle balance for near vision should be made with the Bishop Harman Diaphragm test, described below

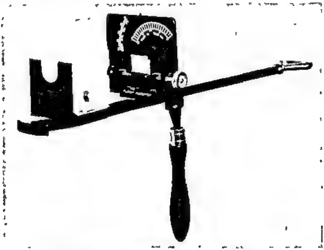

Fig 34—Bishop Harman diaphragm. The candidate places the triangular bridge on the right hand side of the illustration against his upper lip

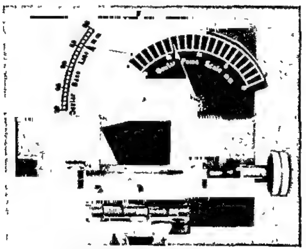

Fig. 35—Bishop Harman diaphragm Close-up view of diaphragm and ocular base line scale

**3. Bishop Harman Diaphragm Test.**—This test is designed to estimate "the desire for binocular vision"; it is a dissociation test and an interpretation of its results is based on those principles. The apparatus (*Figs* 34–36) consists of a card on which appear the numbers 1 to 7 viewed by *the candidate through* a variable vertical diaphragm. The procedure is as follows:—

The interpupillary distance of the candidate is first measured and the ocular base-line scale set accordingly The diaphragm is

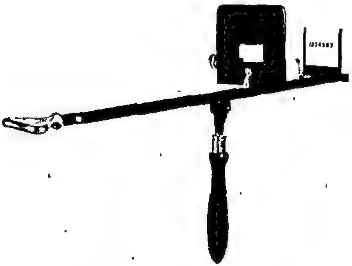

*Fig* 36—Bishop Harman diaphragm, showing card bearing numbers 1–7, with diaphragm in position

opened to its fullest extent Instruct the candidate to look through the aperture at the numbers 1 to 7 on the card. Warn him that one of four things will eventually happen Either (1) the numbers will be divided—usually between the 4 and 5, by a black bar; (2) the centre numbers will crowd together; (3) there may be a difference in the level of the numbers; and (4) one or other of the end numbers may disappear The candidate must state immediately he notices any of these things occurring Place the instrument against the candidate's upper lip and commence turning the screw which closes the diaphragm The rate must be kept constant and *rather fast, or the strain imposed is too severe* and artificial results will be obtained. When the candidate notices a change in the arrangement of the numbers, the position of the pointer on the scale should be noted The test should be repeated to check

the accuracy of the first result. If when the scale registers 5 or more a bar appears, an exophoric tendency is indicated, while crowding suggests esophoria (*Fig.* 37) If one group of numbers is raised above the others hyperphoria is present. The disappearance of the end numbers indicates suppression of one or other eye

**4. Cover Test.**—This test is a simple method of detecting the presence of a phoria or squint, and both eyes must be tested. The

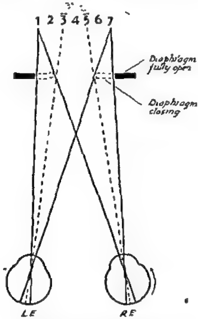


*Fig* 37 —Esophoric response to Bishop Harman test

procedure is as follows Instruct the candidate to fix his gaze on a spotlight at 5 metres Cover one eye, and observe any movement behind the occluder Remove the occluder and note the direction and degree of recovery. Repeat the procedure for the other eye In orthophoria there is no manifest deviation In exophoria the eye will diverge under cover, and recover fixation quickly or slowly when the occluder is removed If no recovery takes place the presence of a squint is revealed, and the eye will only resume its normal position when the other eye is occluded If no movement then takes place, the squint is an apparent one only, and is due to an abnormal setting of the optic axis (the angle

By 'subjective convergence' is implied that reac eyes, fixing a common object approaching them, regi point of failure. This is registered when the ca that he sees a lateral movement of the central line visually fixed by him This range of movement is s pass unobserved by the examiner.

The technique is as follows · To measure objective the candidate fixes his eyes on the rod which is slo from the terminal end of the rule towards his face A of convergence one of the eyes will be seen to hesitate diverge This distance is the objective convergence; subjects it ranges between 5 and 10 cm

The candidate is then told to concentrate on the apparatus and when he says that he can see the black line placed in the cross, the box is moved slowly towards him. point he will state that the line is in the right or left h limb of the cross, this distance is noted

The printed letters on the square are used to test both bi and monocular accommodation. In all cases it will be fou the subjective convergence is greater than the objective

In using this instrument such factors as accommodation, var in pupillary distance, and physical characteristics of the bin gauge, influence the readings, which are judged as follows —

1 Objective convergence of 0–10 cm , normal
2 Objective convergence of 10–13 cm , borderline
3 Objective convergence of 15 cm or over, unfit
4 Subjective convergence of 18 or over should be looked u with suspicion

Broadly speaking, the various types of ocular muscle imbalan which are grouped together under the general heading of heter phoria, tend to increase under conditions of anoxia or fatigue, a a high degree of esophoria (12 to 15 prism dioptres) is liable break down into a convergent strabismus. Alcohol also has th same effect Adler writes "It has been known for some tim that under the influence of alcohol there develops an increasing esophoria which eventually may be sufficient to overcome the fusional fixation reflex and produce esotropia" Carefully con- trolled studies have also been made by Powell and Colson, with similar conclusions Both anoxaemia and alcohol depress the higher centres and any apparent stimulation results in the un- restrained activity of lower centres freed from higher inhibitory control These findings have been corroborated by Mercier and Duguet They examined in a pressure chamber at 16,000 ft , both with and without oxygen, five subjects with an esophoria of 4, 4,

9, 9, and 15 prism dioptres respectively, with an added hyperphoria of 2 prism dioptres in one case. Two subjects with an exophoria of 6 prism dioptres, in one of whom there was also a hyperphoria of 3·5 prism dioptres, were also examined Six out of seven showed that the convergent tendency was increased from 1 to 10 dioptres, which the administration of oxygen reduced to the pre-existing level The hyperphorics experienced diplopia at altitude which remained unaltered with the inhalation of oxygen They conclude that a convergent tendency, although not the rule, is at least of frequent occurrence.

In assessing the suitability of a candidate for a flying career it seems more than justifiable to fail those who have abnormal degrees of heterophoria. From a visual standpoint it has been seen that anoxæmia interferes with the following:—

1. The higher cortical functions of attention and perception.

2. The co-ordination and activity of the oculomotor muscles. McFarland, Knehr and Berens have demonstrated photographically [illegible] visual acuity and muscle balance are normal at ground level. In this connexion the effect upon scanning movements usually adopted in searching a particular sector of the field of vision must also be borne in mind, as also the implications that such a consideration has for pilots in peace as well as in war.

## COLOUR VISION

Colour vision is the ability to recognize the varying colours in the spectrum and is obviously of great importance in aviation because of its application in approaching to land, interpretation of colour signals, aerial observation, etc. Approximately 6 to 8 per cent of male adults are colour defective This term is applied to those people whose colour vision, is, in general, different from and more limited than normal persons

In night bombing during the war it assumed particular importance, on account of varied coloured signals used in modern identification techniques. Success and accuracy of many raids depended entirely on accurate observation of various combinations of colour. In peace-time, correct interpretation of colour signals is vital for safe operations. It is, therefore, necessary to reject all degrees of colour blindness except very minor ones

Colour perception is a sensation, and depends on the length of light waves striking the retina Normal colour vision exists only round the fovea, and as the periphery is approached colour vision

is gradually lost. Many tests have been devised for estimating colour vision, and the primary one which is still used is that of Ishihara plates The candidate is tested on these plates at a distance of 2 ft. in a good light If he passes this test, his colour vision is considered satisfactory If his response is doubtful or unsatisfactory, he is further tested on the Edridge-Green lantern, which consists of a light of standard intensity viewed through varying apertures and with different coloured filters interposed, consisting of graduated shades of red, green, amber, and white

A more satisfactory test, however, is that of the Martin lamp which is now widely used, and is the standard test in the Navy and Merchant service The candidate is tested at 20 ft in a darkened room when various colours at a standard intensity of illumination are displayed Only three colours are used, signal red, signal green, and white, in combinations of two at a time, red-red, red-green, white-red, etc., and the candidate is requested to identify those shown Correct interpretation of the colours shown indicates normal colour vision

Results of these tests are assessed as follows —

1 Colour vision normal Passed on Ishihara plates

2 Colour vision defective, safe. Failed Ishihara, passed colour lantern

3 Colour vision defective, unsafe. Failed Ishihara, failed colour lantern

It is probable, however, that in the near future there will be two assessments only, namely, colour vision safe and colour vision unsafe

## NIGHT VISION

This subject assumed greatly increased importance in the war, first by reason of British night fighters requiring it for defence against German attacks on this country, and later in the war, when the circumstances were reversed, and the allied night bombing offensive came into full swing It is important in civil aviation now that so much flying is done at night, and take-offs and landings have to be made under conditions of low illumination as a matter of routine

The problem is in no way diminished by the greatly improved and vastly expanded technique of instrument flying which has concentrated the attention of the pilot inside, rather than outside, the cockpit. The importance of a pilot being able to see ground signals, the lights of other aircraft, and other forms of illumination under conditions of poor visibility, or indifferent illumination at night-time, cannot be over-estimated

In studying this subject, the questions which have to be considered are how night differs from day vision, what extrinsic factors affect it, how it can be improved in any individual, and how it can be used to the best advantage.

area the sensitivity is fairly constant up to about 40° from the centre.

In the central macular area there are no rods, this area being entirely covered by cones up to a limit of between 2° and 4° from the centre. The greatest concentration of rods is found immediately adjacent to the macular area about 12° to 18° from the centre, and here, as may be expected, the best results are obtained in vision by night It extends up to about 40° from the centre

Rods are not sensitive to colour or fine detail. True perception of colour is, therefore, not possible with night vision A person can distinguish between a light and a dark colour at night but this is due to the difference in the intensity of the reflected light and in no way related to colour vision.

Visual purple is essential for the proper functioning of the rods, and is produced in the presence of vitamin A and absence of light; deficiencies of vitamin A in the diet result in a diminution in night visual acuity. Full activation of visual purple which results in a 10,000-fold increase in the sensitivity of the rods, is not attained until 30 minutes has been spent in a completely darkened atmosphere (*see Fig.* 41) Visual acuity is lowest at the intermediary period between daylight when the cones are used, and night-time when the rods are used, because at such a time neither sets of organs are being used to their full capacity.

In direct contrast to photopic vision, which is essentially a function of the cones, and which has been proved to be extremely resistant to anoxæmic conditions, night vision—essentially a function of the rods, is extraordinarily sensitive to any reduction of oxygen or to any alteration in the *p*H of the blood A marked contraction of the visual field plotted by Livingston's method of rod scotometry is shown after only 15 minutes without oxygen at an altitude of 17,000 ft As might be expected in so delicate a function, there is considerable variation not only in different *individuals but also in the same subject.* Whereas the average percentage decrease in range of night vision is 5 per cent at a height of 4000 ft, it is 40 per cent at 16,000 ft, under starlight conditions (*see* p 61). This is discussed more fully in the chapter on ANOXIA (p. 184) Matthews found that an alteration in the

respiratory rhythm can cause a variation of the content and pH of the blood which is sufficient to changes in night vision

Kekcheyev claims that the fluctuations in night isolated processes but part of a diffuse autonom found that the threshold varied with the pulse-rate blood-pressure, the respiration-rate, and the electrica the skin to direct current Drowsiness causes a sl in the sensitivity of the eye, and conversely, certain sti

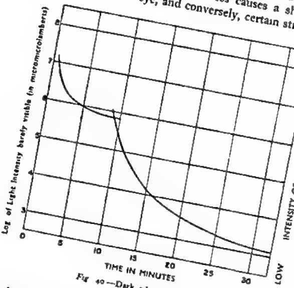


Fig 40.—Dark adaptation curve

taste and cold raise the rod threshold During the recent wa the inhalation of oxygen from the ground up was found to b essential for the preservation of scotopic vision at altitude

Factors which influence night vision are as follows —

**1. Dark Adaptation and Glare.**—Everyday experience shows that on going from bright daylight into a darkened room, a person is completely blind to everything inside. Gradually, however, adaptation takes place until at a later stage, in a dimly lit area such as a cinema theatre, it is possible to see a considerable amount of detail This process may be continued to a further stage, and if an individual is placed in a completely darkened room, the sensitivity of the eye will increase still further, and there will be increased production of visual purple. The complete course of

adaptation to darkness on going from a bright environment into a fully darkened room is shown in *Fig.* 40.

In this figure the curve is obtained by measurement of the amount of light which can just be seen at various time intervals after entry into a dark room. The lower the curve the lesser is the brightness of the light perceptible, hence the greater the sensitivity of the eye. The change in the amount of light which is visible at the beginning of the curve and after 30 minutes indicates a 10,000-fold increase in sensitivity. It will be noted

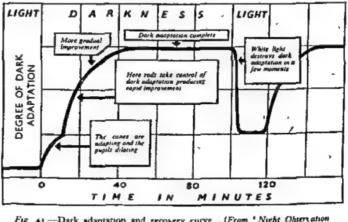


*Fig* 41.—Dark adaptation and recovery curve (*From 'Night Observation from the Air' Royal Air Force crown copyright reserved*)

that the rate of decline beyond 30 minutes is very small, and that sensitivity does not improve greatly thereafter.

It is important to realize that, although it requires about 30 minutes to attain this maximum sensitivity, it can be entirely lost by a brief exposure to the original bright environment, and the whole process of dark adaptation would have to be repeated in order to regain maximum sensitivity. This is demonstrated in *Fig* 41. The amount of time required to regain sensitivity depends on the intensity of bright light to which the eyes are subjected in the interval Thus, in preparing for any night operation, 30 minutes is a minimum time during which dark adaptation should take place, and when in the air it is essential that crews should avoid any form of glare or looking at brightly lighted instruments or cabin lights as thereby night visual acuity will be lessened

**2. Methods of Lighting.**—The lighting of the interior of an aircraft is important for a variety of reasons.

*a* The maximum clarity is required for the reading of all dials, instruments, etc

*b*. There must be a minimum of glare in order to avoid visual fatigue and dazzle

*c*. The light used must be that which has least bleaching effect on visual purple, so that optimum night vision is available at all times

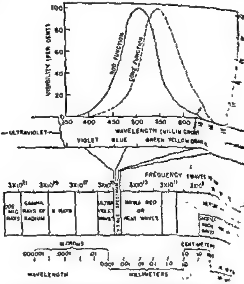


*Fig 42*—*Sensitivity of retina to various wave-lengths (From 'Human Factors in Air Transport Design', by R McFarland By ... Hill Publishing Co)*

Briefly the various means by which this can ... follows —

*a* Direct white lighting

*b*. Indirect white lighting

*c*. Fluorescent dials, illuminated directly

*d* Luminous dials

*e*. Coloured lighting, the principal colo... orange-red, or yellow

*f*. Ultra-violet lighting

For the purposes enumerated earlier a... than one system has been shown to be ... following extensive trials the following ar... the most effective to date Cockpit illu...

orange-red lighting of a wave-length of not less than 580 μ (*see Fig.* 42) which can be rheostatically controlled; the figures on the instrument dials are painted with fluorescent orange paint illuminated by indirect ultra-violet light of a wave-length not less than 365 μ. This should result in a brightness contrast of not more than 10 : 1; greater contrasts being definitely tiring to the eyes.

The reasons for this choice are as follows:—

*a.* Orange-red lighting has been found by experiment to cause the least bleaching of visual purple, at the same time as giving adequate illumination. Red would be preferable if a suitable paint of this colour could be secured.

*b.* Fluorescent dials illuminated by ultra-violet light of the wave-length indicated give clearer readings, and are less tiring, than white lighting on black dials or luminous figures.

*c.* Indirect lighting, by reducing the intensity of light impinging on the retina, is less fatiguing than direct light.

The following additional precautions should be observed when lighting is considered.

*a.* Reflected light, whether from the aircraft lighting itself, or external lights, should be prevented as far as possible. The glass of wind shields, highly polished metal surfaces of instruments, and celluloid map covers are all offenders in this respect.

*b.* Rheostatic control for all lighting should be provided, so that only the minimum intensity of light need be used at all times. When necessary it can be increased for a short period.

*c.* Incidental light from other sources should be screened. Thus, a light trap, in the form of some curtains, should be provided between the cockpit and other compartments.

*d.* Torches for casual use should have orange-red, not white, lighting.

*e.* Ultra-violet lighting should be well shaded at all times.

An important point, often forgotten, is that even at night, pilots should be warned against allowing too much light to fall on the retina. Thus a prolonged flight under a tropical moon over smooth water, may, by reason of the intensity of direct and reflected light, appreciably reduce a person's night visual acuity, and should be guarded against by suitable measures, such as blinds or screens, in order that when a landing has to be effected the maximum visual acuity is available. The above considerations, if properly and intelligently applied, should result in a high degree of visual efficiency at night being maintained.

**3. Oxygen and Anoxia.**—Rods are very sensitive to small degrees of oxygen lack, and the ability to see at night is decreased by exposure to altitude. Thus at 12,000 ft. without oxygen,

percentage decreases in range of night vision when oxygen is not used, are as follows —

| *Height in Ft* | *Average per cent Decrease in Range of Night Vision* |
|---|---|
| 4,000 | 5 |
| 6,000 | 10 |
| 8,000 | 15 |
| 10,000 | 20 |
| 12,000 | 25 |
| 14,000 | 35 |
| 16,000 | 40 |

The above figures relate to starlight conditions Under darker conditions the decrease will be greater, while by moonlight it will be less. Any additional activity resulting in use of oxygen by the tissues, such as moving about the aircraft, will still further reduce night vision due to reduction in the oxygen available. Such disadvantages can be eliminated by an adequate supply of oxygen, and in order to avoid any interim period of bad dark-adaptation it is advisable to use oxygen from the ground up when operating at night

**4. Vitamin A.**—This, as has already been mentioned, is an important essential and is necessary in adequate but not excessive quantities It is usually present in sufficient amounts in a normal diet, and trouble from a lack of it is rarely met with In fact, experience in the last war has shown that defective night vision was not a symptom complained of by prisoners of war in Japanese hands, who were subjected to considerable deficiencies in diet over a long period It is important, however, that whenever possible aircrew receive in their diet adequate supplies of food rich in vitamin A such as eggs, butter, cheese, liver, milk, and green vegetables The addition to the diet of any vitamin preparation should not be necessary

**5. Blood-sugar.**—According to McFarland, diminished sensitivity of the retina to low degrees of illumination occurs when blood-sugar levels are decreased (*see Fig* 43) This can be artificially induced by the injection of insulin (*see Fig* 44) and such a reduction in the night visual acuity can be eliminated by the ingestion of glucose Moreover, the ingestion of glucose can, to a certain extent, offset a decrease in night vision due to diminished oxygen supply. It is a well-known physiological fact that oxygen is essential for the functioning of the central nervous system, and it appears to matter little whether the

oxidation process necessary for efficient functioning of the brain is derived direct from the blood-stream or from the oxidation of carbohydrates.

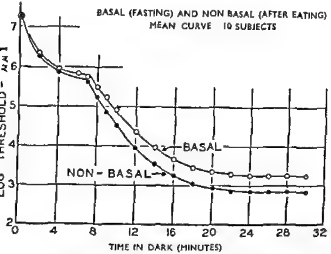


*Fig 43.—Dark adaptation and blood sugar levels (From 'Keeping Fit for Flying', by courtesy of Pan-American Airways system)*

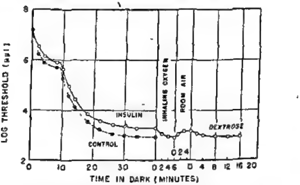


*Fig 44.—Effects of insulin, glucose, and $O_2$ on light sensitivity (From 'Human Factors in Air Transport Design', by R McFarland By courtesy of The McGraw-Hill Publishing Co)*

**6. Carbon Monoxide.**—The presence of carbon monoxide, by reason of the formation of carboxyhæmoglobin which reduces the oxygen-carrying capacity of the blood, diminishes the supply to the tissues and, for this reason, impairs night vision. Carbon monoxide is present in engine exhaust fumes and cigarette smoke, and can be counteracted by an adequate supply of oxygen and proper ventilation.

**7. General Conditions.**—As with intensity of illumination of low degree it is important that all the light possible should fall on the retina, any factors tending to influence this adversely will lower efficiency. Attention to apparently trivial details such as scrupulous cleanliness of the windscreen and goggles, avoidance of any reflected light in the aircraft, and the lowest possible illumination for instruments consistent with clarity, is of greater importance than is often realized.

**8. Practice.**—It has been found that an important factor in the establishment of good night vision in aircrews is that of teaching them to practise 'off centre' viewing. The object of this practice is first of all explained to them and they are told that maximum intensity of night vision, unlike day vision, is not obtained from the centre of the retina. Subsequently they are given practice in darkened rooms with varying models of aircraft, or coastal and geographic scenes, which teach them to use the correct part of the eye for seeing at night.

Gratifying results have been obtained from such methods, and a very useful adjunct has been the introduction of a specialized gymnasium, where aircrew wearing dark-adaptation goggles do gymnastics, and play games, such as hockey, etc., and in general adapt themselves to living under night conditions. The comparison of individuals' night visual capacity before and after the introduction of these measures is quite remarkable.

**9. Warmth and Comfort.**—While the exact reason for the importance of this factor has not yet been determined, it is undoubtedly the case that warmth plays a part in an individual's night visual capacity. It is likely that, in general, all metabolic processes are slowed down when an individual is cold, and a well-fed, warm, comfortable person has greater night visual acuity than a cold and uncomfortable one. Probably the general factor of fatigue is of importance in such cases. Kekcheyev claims, on the other hand, that cold stimulation enhances an individual's night visual capacity.

**10. Smoking.**—Smoking, by reason of the relative state of anoxia produced, results in a diminution in night visual acuity. This is discussed in detail in the chapter on SMOKING (Chapter VII).

**11. Alcohol.**—The presence of alcohol in the body induces a relative state of oxygen lack due to a diminished capacity of the body-cells to utilize oxygen. This results in greater oxygen requirements at all altitudes. Night vision is thus impaired owing to the peculiar susceptibility of rods to oxygen lack (*see* p. 60).

**12. Scanning.**—While this factor cannot be strictly associated with the physiological features of vision, it bears a close relation

to night visual acuity in the same way that practice does. All that is implied in scanning procedure is that some simple geometrical method is used to ensure that a person covers the whole field when searching a darkened area.

The importance of scanning lies in the fact that an individual who is searching the skies at night frequently does not know for what he is looking, or rather, he has not got any predetermined ideas of what he will see, which is a very important aid to visual fixation. The first glimpse he obtains may be a steady light, a flash, or a glowing exhaust, from which he is expected to pick out the dim silhouette of another aircraft. When imagination is tempered with fear and apprehension, and there are other diverting interests such as flashes, coloured lights, or auditory impressions received over the radio and intercommunication system, it will be seen that accurate, careful, and unemotional scanning is a very highly trained procedure.

A simple method of scanning, which has been most effective in practice, is for the scanner, starting in the top left-hand 'corner' of the area to be scanned, to proceed in a straight line to the top right-hand 'corner', then down through an angle of 15°, retracing his scan in the opposite direction, then down again, continuing this process until the whole field of vision has been covered. A complete unit of search should not take more than 30 to 40 seconds.

**13. Range.**—Night visual range under optimum conditions for the average person has been estimated as follows:—

| *Conditions* | *In Front Range in Ft* | *Below Range in Ft* |
|---|---|---|
| Starlight, clear night, no Moon | 700–900 | 300–400 |
| Full Moon, no cloud, over land .. | 700–900 | 300–400 |
| Full Moon, thinly veiled, with cloud over land .. | 3000 | 500 |
| Full Moon | 1500 | 1000 |
| Full Moon, reflected above clouds | 5000 to 7000 in all directions | |

This is represented graphically in *Fig.* 45.

**14. Other Factors.**—A number of Soviet scientists (Kharkov, Semyonovskaya, and others) have shown that weak, brief stimulation of certain other sensory organs increases night visual sensitivity. Subsequent prolonged stimulation of the same organs, however, reduces it. Thus, weak stimulation of the auditory, olfactory, and gustatory organs for a short period increases night visual acuity. Repetition of the stimuli, however, results in a diminution. It is postulated that this change in sensitivity of one sense organ by the stimulation of others is brought about by three channels: intracranial relationship in the central nervous system, autonomic

reflexes, and the humoral route. Proprioceptive stimuli (joints, muscles, tendons) and enteroceptive (internal organs), however, have no effect.

Caffeine, by its direct action on the cerebral cortex, improves night vision for a short time, but drugs in general do not have any beneficial effect.

The effect of other physiological variables on dark adaptation as measured by the Craik adaptometer, has been investigated on a small number of subjects, with the following conclusions (Matthews).

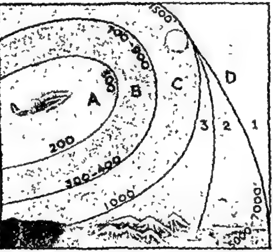


*Fig.* 45.—Schematic representation of night visual range under optimum conditions. A, Dark night. B, Starlight, clear night. C, Full moon. D, Reflecting effects of moon—1, against cloud. 2, on water. 3, on snow. (*From 'Hints on Night Vision.' Royal Air Force crown copyright reserved.*)

Exercise favours dark adaptation, as also does hyperventilation, the effects of which are noticeable after 10 minutes and continue to increase up to 30 minutes. The effects of hyperventilation can be abolished by the application of 3 per cent carbon dioxide. Ammonium chloride (15 g.) slightly increases the powers of dark adaptation up to a period of 1 hour, after which a decrease is observed. The breathing of pure oxygen at ground level has no effect.

**Estimate of Night Visual Capacity.**—At one time it was considered that an individual's night visual capacity could be measured in terms of estimation of rod function, following a specified period of dark adaptation, but other factors, such as interpretation,

were later appreciated to be of equally vital importance, and therefore a test was devised (Livingston) which took these into account

The apparatus used was called the rotating Hexagon, and consisted of a series of illuminated letters and objects, mounted on a movable screen The theory and technique of the examination was as follows The subject to be tested was first of all dark-adapted for 30 minutes by wearing dark goggles He was then taken to a completely darkened room and placed before the Hexagon at a fixed distance, the goggles were removed, and he was told to identify the objects he saw in front of him

The Hexagon was illuminated to a standard degree of illumination by a series of filters. The objects to be identified consisted of four letters and two simple objects (such as a ship, arrow, aircraft, etc.) in each test There were four tests lasting 3½ minutes each The nature of the test was explained to the candidates beforehand so that they had an idea of what to look for The maximum number of objects to be identified was 32, and this was the highest number of marks a candidate could obtain In practice about 3 per cent of personnel got full marks, and about 1 per cent failed to score at all

The test was admittedly based on arbitrary standards, but in practice it was found that an assessment of an individual's night visual capacity made with the Hexagon bore a significant relationship to that person's performances at low illuminations under operational conditions The question of assessing an individual's fitness for certain tasks such as gunner, pilot, or bomb-aimer was based on comparison of the two tests, the one academic, the other practical, and on the figures obtained standards were built up. This apparatus is no longer used

**Differentiation between Rod and Cone Activity, by Scotometry.**—The term 'night vision' actually implies the use of cones as well as rods, although the latter are largely responsible for vision under conditions of low illumination. In twilight, moonlight, or bright starlight, the intensity of light entering the eye is adequate to bring the cones into play, and there are many occasions where mixed rod and cone vision is used

If the fields of rod vision are mapped out by means of self-luminous targets of such low intensity as to be far below that required for cone vision, some interesting facts emerge.

First, wherever the retina is completely covered with cones there is a scotoma. This is true of the macular area The scotoma is remarkably constant in area and shape, being oval, limited on each side of the fixation point to 1·5° and above and below to 2°. In certain instances there is an invasion of the macular area with

is of importance in showing that visual acuity at night depends on

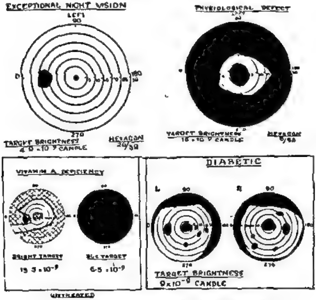


*Fig* 46—Scotometry findings recorded in various conditions (*Reproduced by kind permission of Air Marshal P C Livingston*)

both foveal and parafoveal vision, and not one or other alone As stated elsewhere, the maximum concentration of rods form a ring around the centre of the retina

Rod scotometry provides interesting data in connexion with

vary widely with different subjects

## UNIOCULAR VISION

For some time it was considered vital that a pilot should have binocular vision in order to carry out air-to-ground approaches and

landings, but experience has shown that this is not essential to successful flying and many pilots fly quite successfully using only one eye

The technique requires considerable training, but offers no insurmountable difficulty, the important factor being the pilot's power of depth perception.

Depth perception, using only one eye, depends on the following factors —

1. The apparent size of objects, the dimensions of which are already known.

2. The colour of objects as modified by distance It is well known that the colours of objects at close range are considerably modified by distance. Thus green trees will look a greyish-purple when seen at long range. Such colour effects are frequently used by artists to convey the impression of distance and depth.

3 The partial obstruction of distant planes by objects which are nearer to the observer.

4 Shadows cast by one visual plane upon another.

5 The intensity of light reflected by an object.

6 Perspective Whether in binocular or uniocular viewing, perspective is always of importance, but its value is greatly enhanced by practice, and the experienced pilot appreciates its importance as an accurate adjunct to other factors in depth perception.

7 The intersection of objects with the horizontal plane. Thus the trunks of trees compared with the boundaries of a field, help in the assessment of relative distance

8 Parallax is one of the most important factors in uniocular depth perception. It is known that an object farther away than the one viewed moves in the same direction as the eye, and one nearer than the object viewed moves in the opposite direction to the eye; interpretation of this knowledge is developed to a high degree in estimating distance when one eye only is used

9 Accommodation This is relatively unimportant, but the effort of accommodation required for viewing objects at different distances is appreciated and appropriately interpreted by such a pilot when an approach is being made.

10 Practice All pilots using uniocular vision require practice to accustom themselves to the relative importance of the various factors involved.

11. Visual acuity Visual Acuity of not less than 6/6 is essential with good definition of light, shade, and overlapping contours.

Utilization of the above factors results in a satisfactory technique being maintained, and such pilots can, and do, fly with complete safety.

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## *CHAPTER IV*

# HEARING

## GENERAL

ACUITY of hearing, although not so vital to aircrew personnel as acuity of vision, is nevertheless extremely important for a variety of reasons associated with the control of an aircraft; correct auditory interpretation of radio signals or the human voice is essential to safe aircraft operation.

Good hearing is necessary among other things, for the following reasons —

1 **Intercommunication in the Aircraft between Various Crew Members.**—The proper integration of aircrew duties by the appropriate members of an aircraft is essential for safe and reliable operation

2 **Air-to-ground and Air-to-air Intercommunication.**—This is vital for the reception of weather reports, information concerning conditions at airfields, for obtaining positions and bearings, communication with other aircraft, landing aids, or any occasions when contact with the ground is desired. It is of particular impor- [illegible] its exact position in the air despite minimum visibility due to clouds, fog, or other weather conditions. In such cases it is absolutely vital that reception is unimpaired, and a pilot's ability to recognize vowels and consonants completely accurate.

3 **Radio Signals and Aids.**—Just as air-to-ground and air-to-air communication by spoken voice is important, so is the correct interpretation of radio signals for the same reason There are many cases where verbal intercommunication is not possible and where the only method of exchanging messages is by radio signals. These are usually transmitted on a high frequency and at considerable speed. Correct reception is essential if they are to be accurately translated

4. **Other Airfield Approach Systems**—These rely for their accuracy upon a pilot interpreting the changing note of a

constantly emitted radio beam. Thus, when approaching an airfield if he is directly on the beam he hears a constant note of certain

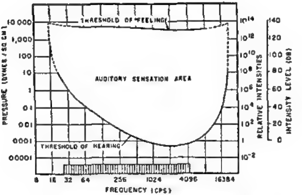


*Fig* 47—Normal limits of hearing sensitivity in human subjects (*After McFarland*)

## EXAMINATION OF THE EAR

The first requisite of good hearing is a healthy ear Thus, on examination there should be no perforation of the drum, no evidence of otitis or discharge from the ear of any sort, no marked cicatrization, and no signs of vestibular disease Small perforations of the drum if healed, and with no discharge, should not disqualify if auditory acuity is unimpaired

In addition to these points in examination, there must be complete patency of the Eustachian tubes on both sides Unless a candidate can clear his ears adequately he is bound to have trouble when flying, due to failure of compensation between the middle and outer ear when changes in atmospheric pressure take place Temporary failure to open the Eustachian tube may be caused by nasopharyngeal catarrh or infection of the upper respiratory tract, and such a candidate should be re-examined when healthy and free from infection

## HEARING TESTS

The following tests are designed to assess a candidate's auditory acuity —

**1. The Whisper Test.**—This test is conducted in a quietened room with a minimum of background noise The candidate stands

with the ear to be tested towards the examiner and at a distance of 20 ft. from him An attendant shields the candidate's face to prevent the possibility of lip-reading and at the same time lightly moves a finger, which is inserted into the meatus of the ear not under test, in the way that a violinist obtains a tremolo. This ensures adequate masking of the ear not under test

A candidate is judged on his ability to hear a forced whisper at 20 ft In choosing the words that are to be used, care must be taken to mix sibilants and vowels proportionately. In early stages of high-tone deafness the candidate will find difficulty in interpreting correctly such words as 'resuscitate', 'sister', and 'interesting'. In low-tone deafness difficulty will be experienced with such words as 'father', 'barn', 'rather'.

**2. Tuning Fork.**—A standard tuning fork should be used and each ear tested separately with the fork held 1 cm. from the external auditory meatus The candidate should be tested at 64, 256, and 4096 double vibrations per second. Care should be taken that the tuning fork is held in the correct position and the vibrations produced by 'milking' action on the fork rather than banging it on some hard object, by which overtones and undertones will be produced, which destroy the accuracy of the test.

**3. Audiometry.**—This is the most accurate test of all, and a number of variations can be used in order to obtain an overall assessment of a candidate's auditory acuity.

*a Pure-tone Gramophone Audiometry with Background Noise*—This test is conducted in a quiet, but not sound-proof, room, when candidates are asked to identify a series of words especially selected phonetically for variations in frequency, and played on a calibrated gramophone record A well-modulated male voice is used, and there is continuous background noise simulating aircraft engines, or the average overall noise level in an aircraft cockpit.

There are forty words in the test, and the first six are not counted in the results in order that the candidate may become accustomed to the test Sibilants, consonants, and vowels are intermixed, and marks are computed by the total number of phonetic sounds recognized Thus, the actual words may be wrongly recorded by the candidate, but the correct phonetic interpretation made, when the score will be counted in his favour. Thus, if the test word 'grass' is interpreted by the candidate as 'brass' it counts as a pass The maximum possible score is 100, the average 80–90, and the pass mark is 60.

*b. Pure-tone Gramophone Audiometry without Background Noise.*—In this case the test is conducted in a quiet, but not sound-proof, room, and a sound-calibrated gramophone registers a series of radio

'pips' of different frequencies ranging from 256 to 4096 double vibrations per second Approximately 30 seconds is given for each series of 'pips'. The maximum loss permitted in each group is 20–25 decibels

*c Pure-tone Audiometry*.—This is conducted in a sound-proof room, with a calibrated audiometer which is frequently tested for accuracy The overall noise level in the room must not be greater than 50 decibels when tested against a sound level meter. Candidates are tested on all frequencies from 128 d v s to 8192 d v s,

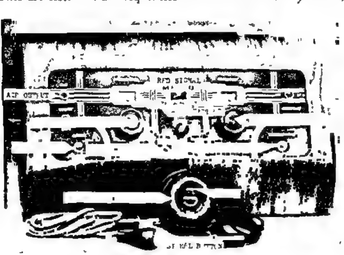

Fig 48.—Pure tone audiometer

each ear being tested separately. Results are assessed on the basis of internationally adopted standards outlined in a subsequent paragraph, and given in greater detail in the appendix.

The following precautions should be observed when conducting the test —

1 It should be ascertained that the candidate being tested has not been engaged in flying for a period of at least 48 hours, preferably 3 days, prior to the test, as any deafness revealed under such circumstances might well be a temporary condition due to recent flying, and not a true cause for rejection

2 The ear-piece should be attached to a headband, and fit snugly round the external ear, in order to ensure that no sound is being conducted into the ear from the other side, due to loose fitting

The pure-tone audiometer is used in the final assessment of auditory acuity, but the other tests present a valuable adjunct when

making final assessment In practice, a high degree of accuracy is obtained by a skilled operator with pure-tone audiometer readings. A typical audiometer is shown in *Fig.* 48

## HEARING STANDARDS

Four standards of hearing have been adopted internationally, the best being Grade I and the poorest Grade IV, details of which are given in APPENDIX I

The highest standard for commercial pilots permits of a hearing loss not greater than 20 decibels at frequencies of 256, 572, 1024, 2048, and 4096 double vibrations per second. Grade II omits the test at the 4096 range. In standardizing these tests it was appreciated that allowance would have to be made for the established fact that many pilots of great experience who have been flying for a number of years have a moderate degree of high-tone deafness, and it would be prejudicial to the interests of all, if such valuable persons were to be debarred from further flying duties on this account. In such cases, therefore, due allowance should be made for a candidate's proven ability and experience.

## PRECAUTIONS TO BE OBSERVED

For testing auditory acuity the following precautions must be observed —

1 The accuracy of the audiometer must be checked from time to time

2. The sound-proofing of the room must be adequate and all apertures, such as doors and windows, be of good fit

3 Care must be taken to exclude transient deafness in the candidate due to such causes as some form of Eustachian catarrh, infection of the upper respiratory tract or ears, and, most common of all, the presence of wax

4 Precautions must be taken to ensure that the candidate is not temporarily deaf owing to bombardment of the auditory mechanism by prolonged recent flight or other similar cause, as this will give an incorrect picture of his true auditory acuity.

Diminution in auditory acuity or high-tone deafness is discussed in detail in Chapter XIX

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## CHAPTER V

# DIET AND NUTRITION

## INTRODUCTION

WHEN considering diet in relation to flying, no differentiation should be made between passengers and aircrew. The highest possible standards for all in quality and quantity should be aimed at In the case of aircrew, it is essential for their optimum efficiency, as a means of preventing the onset of fatigue, and also as a means of preserving the highest possible standards of physical fitness.

For passengers different considerations apply. Commercially it is an extremely sound psychological proposition to feed the travelling public well A well-fed person is a contented person Even with the most stringent food regulations, it is possible to produce excellent meals with good cooking, modern refrigeration, canning, and quick-freezing methods. Unsuitable diet will result in digestive disorders, including constipation, dizziness, headaches, nausea, and mental fatigue, all of which are accompanied by mental and physical discomfort.

## PHYSIOLOGY

**1. Composition of Food—Essential Nutrients.**—A dietary which will maintain health and maximum efficiency must contain the following constituents in balanced amounts. carbohydrate, fat, protein, vitamins, mineral salts, and water The first three of these supply the energy derived from the diet, which is the most important essential Any diet which is deficient in energy or calorific value is a bad diet, no matter how adequate it is in respect of other nutrients.

Energy is most easily available to the body when supplied in the form of carbohydrate, and of the carbohydrates the simple sugars, including glucose and ordinary cane sugar, are the most readily available. *These foods, therefore, are of particular value in the prevention of fatigue* The total energy value of a diet should be about 3000 calories daily. Of this amount approximately 60 per cent is contributed by carbohydrates, 25 per cent by fats, and

15 per cent by proteins There is a considerable variation, however, in the contributions from the different classes of nutrients The energy needs of the body will be satisfied provided food containing

energy per unit of weight than either carbohydrate or proteins, and therefore fats are particularly valuable in increasing an individual's resistance to exposure and cold

The organic matter of the body is essentially protein in character, and in order to maintain the body structure a constant source of dietary protein is essential to effect repair, and to replace the constant wastage of this constituent During growth protein is laid down in the tissues and therefore a high dietary intake is necessary at that time Any excess protein is used as a source of energy Protein is not liable to be deficient in any diet fed in the air, since high palatability is essential, and palatability cannot be achieved without the inclusion of large amounts of high-protein foods such as meat, fish, poultry, game, eggs, and dairy products

Generally speaking, vitamins are adequately supplied by good mixed diets The most likely deficiency is vitamin C (ascorbic acid) To supply this factor it is important to give adequate amounts of fresh vegetables, fruit, or fruit juices

The possibility of deficiency of mineral salts is not great, provided a good mixed dietary is taken.

Water intake, which of course comes from beverages and also from solid food, is usually adequate In tropical climates, however, a larger intake of fluid is essential to make up for losses in sweat, and therefore in hot climates people should be encouraged to drink by the provision of palatable fluids at frequent intervals

**2. Timing of Meals.**—This is a very important factor in feeding during flight which is frequently not adequately appreciated An empty stomach is to be avoided in flying for the following reasons First, it predisposes to airsickness, because an empty stomach tends to contract more frequently than a full one, thus encouraging the onset of the condition , and, secondly, it increases fatigue and lowers efficiency Foods, particularly the carbohydrates, are converted in the body into sugar, in which form they are utilized for the production of mental and physical energy Too little sugar in the blood leads to fatigue, which can often be quickly relieved by the ingestion of sugar in some form such as sweets or chocolates Efficiency is lowered for the same reason, namely, a lowered level of sugar in the blood Thirdly, considerable discomfort, and in some cases pain, may be caused by an empty

stomach. In respect of hours of meals, physiological times, and not chronological times, are important, i.e., the feeding programme should be based on providing food as close to normal meal times as possible and not at times governed by local conditions. 'Stomach time' is much more important than watch time.

Thus passengers who may, in the course of one flight, encounter a five-hour difference in clock time will not appreciate being wakened up for a meal just because it is time for breakfast by local time, and contrariwise, a person may well be hungry during official 'night time' because, were they to be still at their point of departure, it would now be time for a further meal

Four hours is the maximum time interval which should be permitted between full meals, and a two-hours' interval the ideal to be aimed at between food of any sort. This does not imply a large meal every two hours, but as far as possible the programme *should be divided into full meals (three to four courses) and snacks.* A 'day's' programme (24 hours) might therefore be as follows:—

| | |
|---|---|
| *8 a m* | *Breakfast* |
| 10 a m | Hot drink and snack |
| 12 noon | Lunch |
| 2 p m | Snack and drink |
| 4 p m | Tea, including cakes |
| 6 p m | Light snacks, such as small hors-d'œuvres. |
| 8 p m | Dinner |
| 10 p m | Supper—hot drinks, sandwiches, and sweet biscuits |
| *10 p m –8 a m* | *As required* |

A programme such as this will ensure the near attainment of the ideal in flying, namely, *small quantities of food at frequent* intervals.

If flying takes place through the night, light refreshments should always be available on request, and encouraged by those responsible, as persons may frequently feel hungry and in need of food, but may be diffident about asking for it at such a time. Furthermore, it is an important factor in preserving the efficiency of aircrews at night by reason of the maintenance of adequate blood-sugar levels

If the day's flying programme has to be altered, the principles enumerated above should be maintained as far as possible, i e., if, having flown through the night, breakfast is at 6 a m , the steward should provide a hot drink and biscuits at 8 a m. and another snack on board at 10 a m. As far as possible meals in the air should be given so as to integrate with those on ground, in order that a smooth and continuous time-table may be maintained for all, and *minimum* dislocation of normal life experienced. An important factor which is often forgotten, is that on embarkation people may have been many hours without food, owing to travelling time getting to the airport, or ticket and other formalities, etc.

The drawbacks in meal time-tables referred to above particularly apply to very early morning starts, where passengers and crew may have to rise at 4 a m. to be transported to an airport, where they wait about for some time, possibly in the cold, and finally get a meal in the aircraft, perhaps four hours later Such a contingency could be avoided by providing an adequate (but not necessarily large) meal on the ground before they leave Such a practice would prevent what is often extreme discomfort before a flight even begins It is important also from the point of view of the efficiency of the aircrew on such occasions They may have had a tiring previous day's flying, a not too restful night, and the benefit that can be achieved by a palatable hot breakfast at such a time is out of all proportion to the trouble taken in preparing it

**3. Digestion.**—Food is of no use unless properly digested and absorbed by the body The following factors influence satisfactory digestion Small quantities of food at frequent intervals are more easily absorbed and digested than large quantities less frequently Excessive eating and drinking at any time retards digestion The ideal should therefore be to provide small meals at frequent intervals, with three larger ones per day in order to give the necessary bulk and energy value

Worry and excitement impair digestion owing to three factors First, there are abnormal stomach movements which prevent the proper mixing of foods in the stomach with the digestive juices Secondly, there is diminished liberation of gastric and intestinal secretions Thirdly, there is a partial diversion of the blood-supply from the stomach to other organs Oxygen lack as experienced at altitude impairs digestion, as adequate oxygen is necessary for the digestive process Lack of oxygen delays absorption of food, and also delays emptying of the stomach and secretion of gastric juices mentioned above Gas formation is of less importance than was at one time presumed Provided moderation is observed there are no specific foods which should be avoided, and although it is correct to say that some have a greater gas-forming tendency than others, individuals are differently affected in this respect No foods, however, cause discomfort or pain to the majority of persons if taken in reasonable quantities

Excessive smoking and drinking retard the digestive process and therefore should be avoided This is a matter in which the remedy lies in a person's own habits, and no hard or fast rules can be laid down

**4. Desirable Dietary.**—Points requiring particular attention are as follows All foods should be well cooked, over-cooking rather than under-cooking being the rule Under-cooked food

places a greater strain on the digestive process than properly-cooked food Quantities should be moderate for the reasons mentioned in a previous paragraph. Further helpings should always be provided if requested. Quality should be the highest only, as inferior foods invariably contain a higher proportion of indigestible components. *A high carbohydrate content is desirable* for the reasons mentioned in a previous paragraph, namely, their energy value, and because they provide the important component, sugar. Too many fats should be avoided, as also excessive quantities of cellulose such as beans, cabbage, etc, which may cause discomfort owing to their bulk. Variety is far more important than is often

large quantity of any one food. Lastly, a wider range of essential vitamins and minerals is introduced in the system when the food sources are varied

## SERVICE OF FOOD AND CLEANSING OF UTENSILS

It is axiomatic, but far too often forgotten, that food is useless if it remains on the plate, only that which is eaten is of value. The service of food is much more important than is sometimes realized in this respect, and the following points have an important bearing on the matter. Quite apart from the hygienic and sanitary considerations involved, cleanliness of utensils can be a deciding factor in influencing a person to eat the food put before him. Many a person is put off his food by a dirty plate, knife, or spoon For this purpose an adequate supply of hot water with an effective detergent for the initial cleansing of crockery and cutlery, and a chlorine solution for sterilizing eating utensils after washing up, is absolutely essential. The best detergent is one that has high cleansing properties, is completely soluble, even in cold water, is non-alkaline and non-abrasive. A proprietary product such as 'Teepol' is excellent in this respect

Laboratory examination of aircraft eating utensils from time to time has revealed the presence of large numbers of food-poisoning organisms in the invisible film of grease that is not removed by ordinary washing-up methods A detergent is essential if this film and the dangerous organisms it harbours are to be removed, and so prevented from being passed on to subseq[illegible] users.

After cleansing with water charged [illegible] [illegible]nt, all cutlery should be placed f[illegible] nutes in a v[illegible] water, in which a halazone or [illegible] [illegible]blet has be[illegible] to ensure that

any organisms which still remain are destroyed Crockery and cutlery should be left to dry without wiping Soiled drying cloths constitute a danger, since they serve to re-contaminate utensils already disinfected

Finally, it must never be forgotten that flies are potent carriers of disease and cause intestinal disorders of varying degrees and severity, particularly in the tropics Foodstuffs everywhere must therefore be covered or otherwise protected against contact with flies, and all personnel warned of their liability to contaminate food. As a further precaution all fruits or salads used should be soaked in a dilute solution of potassium permanganate before being served

Cleanliness of food handlers should be a *sine qua non*, but is as often honoured in the breach as in the observance Apart from the [illegible] should be provided for the use of all food servers Nails should be kept short, and a high standard of cleanliness enforced at all times

An awkwardly-laid tray or inappropriate utensils have a more adverse effect than is often realized in putting a person off his or her food Daintiness is an important psychological factor in the serving of food, and some airlines have made great progress in this respect. Thus slotted trays, special containers, and appropriate china and cutlery all play their part in giving a general impression of good food service Good food can be spoilt by bad cooking or indifferent service. Indifferent food can be made quite attractive if well cooked, cleverly garnished, and attractively served Utensils and food containers should be scrupulously clean, and all food that is not used kept in closed containers Foods are frequently spoiled by being served at the wrong temperature This particularly applies to beverages and soups, which are frequently lukewarm or cold Few things are more unappetizing than a tepid meal, and such food has a bad psychological effect on passengers.

## ALCOHOL

Moderate ingestion of alcohol promotes a sense of well-being and increases secretion of digestive juices, as well as stimulating the appetite In addition it allays apprehension and thus further aids the digestive process In small quantities it has no noticeably adverse effect on airsickness and by reason of the effect described above is a valuable adjunct to the diet The above comments on alcohol only apply to passengers Full consideration is given to the effect of alcohol on flying personnel in Chapter VI

## CHILDREN AND INFANTS

The considerations mentioned above are of even greater importance in the case of children, who are much more susceptible than adults to the consequences of erratic or injudicious feeding. If the comfort of the child, parents, and other passengers is to be considered, carefully thought out feeding at frequent intervals will greatly help in this respect. The general comfort of all will be well served by converting a fractious, hungry child into a well-fed tractable one. A special dietary for infants up to 18 months of age should be provided when they are travelling. This has been adopted with great success on some airlines, and is a great boon to mother and child alike. Infants are far more susceptible to changes of diet than adults, and every effort should be made to see that no gross deviation from the normal occurs when small children are passengers by air.

In the case of infants in arms who are not breast fed, proprietary milk mixtures should be kept on the aircraft, and stewards and stewardesses instructed in their preparation. Emphasis should be laid on the dangers of improperly sterilized feeding-bottles, and a specific routine for their cleansing laid down.

## TROPICAL FEEDING

It is not possible to lay down a rigid diet for use in the tropics, because much will depend on the availability of local foods, but there are certain obligations and restrictions which must be observed for the preservation of health. Most of these considerations arise out of the fact that adequate supervision of food handlers and sources of food supply is not possible, and therefore certain rules are necessary to avoid the dangers which arise from contamination. Unless, therefore, the source of supply is absolutely unimpeachable, and can be under constant supervision (a rare state of affairs) the following foods must be avoided:—

1. Undercooked leaf vegetables, greens, salads, or raw fruits, even those with peel on them. Anything which grows on or near the ground is liable to be contaminated with the excreta of animals or natives.

2. Any cold food, even if it has already been cooked, which has been allowed to stand without adequate refrigeration.

3. Milk that has not recently been boiled; this is one of the most fertile sources of bacterial contamination.

4. Food of any sort that may have been handled by natives, or washed in water the purity of which is doubtful.

5. Inadequately cooked meat. Pork is a particular offender in this respect and infection from this meat, when only partly cooked, is commonly met with in the tropics. It is wise in hot climates to avoid pork altogether, as the risks attendant upon its consumption do not justify its use.

6. Fish which has not been correctly refrigerated is a potent source of bacterial contamination.

7. Water of any sort, of which the source and standard of purity are not known. Precautions with regard to drinking water are described in Chapter XXXIV.

8. Ice which may be contaminated. It is a popular belief that freezing sterilizes water. This is not correct, and infection from such sources is well known.

The following foods may be eaten if their preparation is properly supervised:—

1. Hot cooked vegetables.
2. Recently boiled milk.
3. Fresh fruit which does not grow near the ground, picked by known persons, and washed from a known water supply.
4. Well-cooked meat or eggs.
5. Canned or tinned foods, eaten immediately they are opened.
6. Water of known purity, or water which is boiled or purified by a known chlorination process.

The above comments on tropical feeding should be taken as a guide only, and decisions should be governed by local conditions operating at the time.

## RECOMMENDED DIETARY AND MENUS

It is not possible to go into details of all desirable foods. A summary of useful ones in flying, with comments, is given herewith for reference.

| *Foodstuff* | *Comment* | *Notes on Food Value* |
|---|---|---|
| **1. Breakfast**:— | | |
| *Appetizer* Tomato juice, fruit juice, fresh fruit | Very popular | Vitamin C |
| *Cereals* Cold or hot | Save cooking, palatable | Energy value |
| Cream | — | Fat content |
| Sugar | Liberal portions | Maintain adequate blood-sugar levels |
| *Eggs* Boiled, poached, scrambled, fried, or omelette | Always popular, easy to prepare | High protein and vitamin content |

| *Foodstuff* | *Comment* | *Notes on Food Value* |
|---|---|---|
| ***Meat*** | | |
| Bacon, ham, sausages, kidneys, fish of any sort, hot | An excellent fortifier at the beginning of a day | Palatable; high protein content |
| ***Vegetables*** | | |
| Mushrooms, tomatoes | Appetizing, palatable, provide bulk | Vitamin C |
| Fried potatoes | | Carbohydrate value, vitamin C |
| ***Bread*** | | |
| Toast, rolls, etc | Avoid heavily crusted bread Must be fresh Brioche excellent Ensure variety, such as currant, brown, milk loaf, etc. | Carbohydrate value |
| ***Preserves*** | | |
| Marmalade, jam, honey | Appetizers | Sugar content |
| Butter | — | Vitamin A and D, fat content |

**2. Lunch :—**

| *Foodstuff* | *Comment* | *Notes on Food Value* |
|---|---|---|
| ***Soups*** | | |
| Broths | Easily digestible, add potato for carbohydrate value | High protein content |
| Tinned tomato, vegetable, etc | Palatable appetizers | Vitamin C |
| ***Hors-d'œuvres*** | Palatable | High protein content |
| ***Fish*** | | |
| All sorts, including salmon and trout | Palatable and popular | High protein content |
| ***Meats*** | | |
| All roast joints, except pork | Do not spoil with too much gravy | High protein value |
| All poultry | | High calorific value |
| All game | Very popular | |
| Cold meats, various | | |
| Mixed grills | | |
| ***Vegetables*** | | |
| Roast, boiled, and creamed potatoes | Digestible, palatable | Vitamin C; carbohydrates |
| | Popular | |
| Greens and salads | Popular Care in tropics | Vitamin C |
| ***Sweets*** | | |
| Fruit salads, cream, blancmanges, and trifles | All with plenty of sugar | Vitamin C; fat, vitamins A and D |
| Pastries, tarts with jam | — | Carbohydrate value |
| Ice-cream | Very digestible | High nutritive value |
| Hot fruit tart | Popular | Vitamin C; carbohydrate |

| Foodstuff | Comment | Notes on Food Value |
|---|---|---|
| *Sweets, continued:* | | |
| Fruit, all sorts | Popular Care in tropics | Vitamin C |
| Cheese, butter, biscuits | Palatable | Calcium, vitamins A and D |
| Coffee with sugar | Stimulant | Sugar content, caffeine content |
| **3. Afternoon Tea:—** | | |
| Toast, bread, rolls, cakes, sandwiches | Avoid thick, heavy, or crusted bread | High carbohydrate and sugar content |
| Preserves | — | Sugar content |
| Fishpastes | Appetizer | Protein content |
| Tea with sugar and milk | Stimulant | Sugar and caffeine content |
| **4. Dinner:—** | | |
| As lunch | | |
| **5. Snacks:—** | | |
| *Beverages* | | |
| Tea, coffee, cocoa, Ovaltine, etc | Warming Important as stimulants, and caffeine content Sugar where appropriate | — |
| Fruit juices | Refreshing | Vitamin C |
| Sandwiches with butter, meat, fishpaste, cheese or savoury | Appetizing | High protein value |
| Hors-d'œuvres or savouries | — | Protein content |
| Cakes and biscuits | — | Sugar and high carbohydrate content |
| Boiled sweets and chocolate | Prevent fatigue | Sugar content |

## SUMMARY AND CONCLUSIONS

It is apparent that whilst in many cases a suitable dietary is laid own, its application in practice has been very poor owing to lack of ppreciation on the part of those administering it of the desirable rinciples involved. The principal shortcomings appear to be as ollows:—

Timing of meals is frequently bad, insufficient attention being paid to the maintenance of a person's normal daily routine, and for this reason correct intervals between food should be maintained as far as possible. Feeding at night is often neglected, food is frequently served at the incorrect temperature, and variety is lacking

The following points require particular attention :—

Only the best quality food should be used, and aircrews and passengers should have the same food at all times. It should be served in relatively small quantities at frequent intervals, and no person should be allowed to be hungry at any time. Abstention from all food should be discouraged in passengers and forbidden in aircrew as it increases liability to fatigue and air-sickness. Aircrew prefer to go without food altogether rather than eat it if it is unpalatable. This can only result in lowering of efficiency. Particular attention should be paid to timing of meals with reference to physiological rather than chronological times. The approximate calorific value should be 3000 calories per person per day in the proportion of carbohydrates 60 per cent, fats 25 per cent, proteins 15 per cent.

Factors operating against digestion such as fatigue, apprehension, cold, and lack of oxygen, should be carefully watched. In this connexion full meals should not normally be served unless absolutely necessary at heights greater than 10,000 ft. cabin altitude. Strict attention should be paid to the serving of all food at the correct temperature, and the cleanliness of all food handlers and utensils. Sugar is important at all times, and salt should be increased in the tropics to counteract loss through perspiration. Food should be offered frequently at night if awake, but passengers should never be wakened at night-time to be fed.

A satisfactory solution can be obtained only by ensuring attention to all these points. There must be thorough indoctrination of the physiological and psychological principles enumerated above in all concerned with the preparation and serving of food. There must also be adequate training of all food handlers and servers, which must be followed up by constant supervision. Good feeding based on sound principles will go far to ensure physically fit aircrews and contented passengers.

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*CHAPTER VI*

# ALCOHOL

## INTRODUCTION

The virtues and vices of alcohol as a beverage have been greatly exaggerated. It can be of undoubted benefit if wisely indulged in. On the other hand, it can have undesirable and dangerous effects on the human system.

The alcoholic content of various beverages varies considerably, and this fact must be taken into consideration when reviewing the subject as a whole. In spirits such as gin, whisky, or rum the alcoholic content is high, as it is also in some wines, particularly champagne, sherry, port, and liqueurs. In beers, lagers, cider, and some natural wines, the alcohol content is relatively low. (*Table VII*)

*Table VII*

| Beverage | Amount and Dilution | Equivalent Volume of Pure Alcohol | Relation to Meal | Average Maximum Blood Concentration |
|---|---|---|---|---|
| | c c | c c | | mg/c c |
| Gin | 126 (87 proof undiluted) | 55 | Before | 1·01 |
| Gin | 126 (87 " " ) | 55 | After | ·41 |
| Whisky | 122 (90 " " ) | 55 | Before | ·89 |
| Whisky | 122 (90 " " ) | 55 | After | ·35 |
| Beer | 1222 " ) | 55 | Before | ·44 |
| Beer | 1222 | 55 | After | ·22 |

## PHYSIOLOGICAL CONSIDERATIONS

Alcohol is completely soluble in water and is absorbed very rapidly in unchanged form from the stomach and small intestine into the blood-stream. One-quarter is absorbed from the stomach, three-quarters from the small intestine, whence it is quickly distributed throughout the whole body, including the brain. None is absorbed from the large intestine. The highest concentration is

in arterial blood, with lower concentrations in the liver, spleen, muscles, cerebrospinal fluid, and brain respectively. At a later stage the concentration in the brain is higher than in other organs. An important point to note is that alcohol remains in the cerebrospinal fluid longer than in the blood (*Fig* 49). Symptoms of intoxication vary directly with the concentration in the blood, which concentration is in turn directly dependent on the concentration of the dose ingested. Thus ingestion of spirits will result in a much higher blood concentration than ingestion of beer.

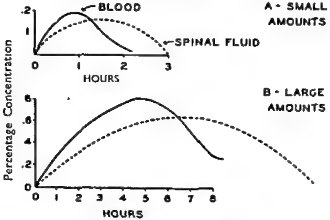


*Fig* 49.—Comparison of concentrations of alcohol in blood and cerebrospinal fluid (*After McFarland*)

Blood samples show that the maximum concentration of alcohol is found within a half to two hours after ingestion, the quantity present in the blood being directly proportional to the original dose. Absorption of alcohol is retarded by the presence in the stomach of food, especially fats (*Fig* 50), and is dependent on the rate at which it is ingested. Thus, if ingested slowly, and time is allowed for oxidation in the stomach, a smaller quantity will be absorbed into the blood-stream.

Elimination of alcohol from the body occurs largely by oxidation, less than 5 per cent being excreted via the breath, urine, and skin, and it disappears from the blood-stream at a constant rate, which is not influenced by external factors such as exercise, hyperventilation, or increased urinary output. It is, however, oxidized more rapidly in cases of habituation.

A blood-alcohol content of 0.15 per cent causes mild intoxication, and 0.25 per cent definite drunkenness, but the latter figure may

be excepted when considering habitués. Evidence of alcohol in the blood may be demonstrated up to 72 hours after it has been consumed.

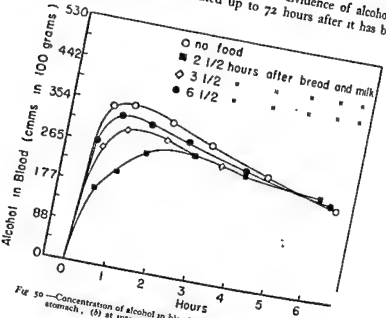


*Fig 30*—Concentration of alcohol in blood after ingestion: (*a*) in empty stomach, (*b*) at intervals after food (*After Mellanby*)

## EFFECTS OF ALCOHOL ON MAN

The following symptoms are present in varying degrees after the ingestion of alcohol.

**1. Psychological.**—There is a general feeling of euphoria and well-being, quite unrelated to the actual condition. A person's sense of proportion, feeling of responsibility, and vigilance in the execution of his duties are reduced. He is carefree and over-confident, self-criticism is impaired, and, most serious of all, he over-estimates his ability to perform the tasks before him. There is a lessening of inhibitions and latent fears, and a feeling of contentment and relaxation

The effects of alcohol on attention and concentration is of particular importance to a person operating an aircraft. McFarland states that focused attention is a psychological condition in which there is a special fusion of sensory impressions and mental organization. Attention normally has a wave-like character, and fluctuates, so that even though we go on looking at the same object, we usually find different phases or meanings coming successively before our inner view Experiments indicate that a subject who has taken

alcohol is less than normally sensitive to extraneous stimuli, and is also less likely to reorganize and integrate mentally the materials to which he is directing his attention. Thus alcohol produces a kind of narrowing and prolongation of attention. The important point is that the focal or attentive consciousness under the influence of alcohol is not normally flexible to stimuli immediately pertinent to what is being observed. Hence 'the concentration of attention' produced by alcohol is attained at the sacrifice of what is usually more important, that is, breadth and depth of mental focus. Alcohol leads to miscalculation and clouded perception, lowered intelligence, and impaired higher mental functions. Of course the mind continues to function under limited drinking, and mental decrement may not be readily observable. That is why the effects of moderate drinking are so often under dispute. But if conditions permit quantitative scoring of performance ability, with practice and maturation fairly well controlled, some slowing and clogging of mental processes is found to be typical of the performance of most people, even after what is considered moderate drinking. Mental behaviour suffers from the fact that the drinker so commonly fails, or is faulty in his mental work of self-checking. After alcohol one is not as versatile in directing thought along appropriate lines to the problems at hand. There is a clumsy mental fumbling for solutions, similar to the clumsiness of movement of hands and feet in attempted motor co-ordination.

**2. Physiological.—**

*a. Brain and Nervous System.*—Alcohol is a direct depressant of the central nervous system, and this action is brought about by several factors. First, it is a tissue poison, the effect of which is to produce an impairment of oxidation in nervous tissue to which condition the latter is particularly susceptible; secondly, it has a depressant action on the synapses, as a result of which all reaction times are slowed; the knee-jerk is impaired, and motor responses to stimuli become progressively more sluggish. The execution of complicated procedures becomes clumsy, motor movements less accurate, and there is a lowering of skill, efficiency, and rate of accomplishment. Acuteness of sensation is diminished, and in some cases alcohol can act as a mild analgesic, an increase of stimulus varying from 12 to 48 per cent being required in certain cases to produce the same sensations in an alcoholic as in a normal person. At the same time there is a subjective feeling of importance, and an illusory feeling of warmth, due to dilatation of the cutaneous blood-vessels.

*b. Respiratory and Cardiovascular System.*—There is a temporary increase in pulse-rate, and rise in blood-pressure and cardiac

output, which is, however, followed by a depression in all three cases. There is an initial slight increase in respiratory volume, which is subsequently diminished. The effects of alcohol have in many ways been compared with the effects of oxygen lack on the human system and many of the effects described are similar. One of the most serious effects of alcohol on the system is the formation of a relative state of oxygen lack, in which the body cells lose their capacity to utilize oxygen. This histotoxic anoxia results in greater oxygen requirements at all altitudes. Thus a person's flying ceiling may be lowered by several thousand feet by the ingestion of even small quantities of alcohol, and he will require oxygen to maintain his efficiency at a correspondingly lower altitude than is usual in his particular case.

*c. Gastro-intestinal System.*—There is a relaxation of muscular tissue in the gastro-intestinal tract, and increased gastric and salivary secretion, but decreased output of pepsin. The sense of well-being and relaxation which is brought about is an aid to digestion when the amount of alcohol taken is not excessive.

*d. Vision.*—The effects of alcohol on the eye are very important because of the vital part that this organ plays in safe flying. One noticeable effect is a diminution in the speed and accuracy of eye movements required in convergence and fixation. A synergic action and co-ordination of the muscles of the eye are made without conscious effort in the normal individual, but experiments have shown that after the ingestion of only small quantities of alcohol, the time of relatively slight eye movements in human subjects show increases varying from 2.5 per cent to 18 per cent. All subjects tested regularly show that alcohol interferes with visual motor functions, and there is noticeable impairment of the ability of the eyes to follow a moving object, or to focus on it when it is brought nearer. In addition to the above factors movements of the lids are noticeably slowed.

Light sensitivity of the eye is considerably reduced after the ingestion of alcohol, and visual acuity thereby diminished. Night vision is even more seriously impaired as the rods are particularly susceptible to the histotoxic anoxia caused. Extensive night vision tests show that responses to low degrees of illumination are reduced and there is diminished dark adaptation. (*See* Chapter III.)

*e. Co-ordination.*—Muscular co-ordination is reduced in all cases, and one of the more noticeable effects is that of speech, which becomes thick and uncertain. Skill tests such as threading needles, typewriting, and other tasks requiring co-ordination of hand and eye are noticeably impaired.

*f Muscular Effort.*—This is noticeably diminished by as much as 12–14 per cent in moderate cases and the mental and physical effort required to perform a particular task is greatly increased

*g. Memory and Learning*—The ability to perform feats of learning and memory in many instances is greatly reduced, and the affected person finds it extremely difficult to collect his thoughts, concentrate, or reduce impressions received to a composite picture

*h Height*—The effects of alcohol on the human system are increased with height, and relatively innocuous concentrations on the ground will affect a person much more severely at height Experiments in this connexion were conducted with mountaineering expeditions Bornstein and Loewy have reported that the concentration of alcohol rises more rapidly, and to a higher level, at altitude than at sea level. Excretion and oxidation, however, proceed at the same rate Psychological tests of visual and auditory acuity, and eye-hand co-ordination clearly show that the concentration of alcohol in the blood is greater, and the effects on the system proportionately increased, at altitude

## CONCLUSIONS AND RECOMMENDATIONS

**1. The Use of Alcohol by Flying Personnel.**—The effects of alcohol on aircrew performance show no redeeming features, and there is no justification for its consumption by aircrews at any time when they are on flying duty, or liable to be flying within 24 hours. Consumption at such times can only lower efficiency, increase fatigue, and greatly increase the liability to accidents By reason of its effect on the higher functions of the brain a person is unable to judge of his relative inefficiency, and often has an exaggerated estimate of his skill, many persons being unaware of the fact that even the smallest concentration of alcohol in the blood causes a noticeable impairment of efficiency Furthermore it is a common and widely-held misconception that during a relatively short period of sleep or rest, alcohol that has been ingested is completely removed from the system This is not so. Evidence of alcohol in the blood may be found from 24 to 72 hours after ingestion according to the quantity taken

The effect of aircrew drinking alcohol when on duty, whatever the circumstances, has a profoundly bad psychological effect on passengers It can only impair the prestige of the persons drinking and the airline they represent, and undermine confidence in their flying ability, sense of duty, and responsibility

**2. The Use of Alcohol by Passengers.**—The factors which influence a decision in the case of aircrew do not operate in the case of passengers, in fact, the reverse is the case

Thus it is desirable in a passenger to encourage a feeling of well-being, freedom from apprehension, relaxation, and general *laisser-faire*. Digestion should be assisted where possible, as also the wish to sleep Excesses, however, are to be avoided, especially in those persons liable to air-sickness, although experiments have shown that small quantities of alcohol in some cases reduce the incidence of this malady Moderate and judicious consumption of alcohol by passengers before, during, and after flight should therefore be encouraged.

The aim of a medical adviser should be to present the facts relating to alcohol consumption and flying in such a manner that aircrews will impose their own code of restrictions on its consumption, rather than that such restrictions should be imposed by regulations Such an ideal should be attainable if properly and wisely handled, but until such a time regulations may be necessary in the interests of safe operations.

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*CHAPTER VII*

# SMOKING

## INTRODUCTION

SMOKING has become such a universal habit to-day that its possible effect on health and efficiency has received less and less attention in recent years It does not, in the experience of many observers, produce any noticeable effects, or severe reduction in efficiency of aircrew, by reason of the fact that few aircrew personnel inhale, or are consistently heavy smokers

## COMPOSITION OF TOBACCO

**1. Constituents.**—The main constituents of tobacco are nicotine, various alkaloids, volatile oils, and a varying percentage of water, together with sundry flavouring essences Glycerin and diethylene glycol are also added to keep the leaf moist. There may also be a concentration of up to 114 parts in a million of arsenic as a result of solutions which are sprayed on the tobacco plant during growth A third of this arsenic content is volatilized in smoking

**2. Tobacco Smoke.**—This is composed of nitrogen, oxygen, carbon dioxide, carbon monoxide, and nicotine Small quantities of ammonia, aldehydes, prussic acid, pyridine, collidine, and tars are present as well as volatile resins and organic acids

**3. Varieties of Smoke.**—Constituents of tobacco smoke can vary through a wide range Thus smoke from the end of a cigar is largely oxidized and contains only a small percentage of carbon monoxide and ammonia That which is drawn through the cigar itself and enters the mouth, however, is not oxidized and the carbon monoxide content is relatively high.

The speed with which tobacco is smoked affects the oxidation process Thus, tobacco which is smoked slowly, allows time for more complete oxidation, the carbon monoxide content, therefore, being low. That which is smoked quickly does not allow time for oxidation, and the carbon monoxide content is high

The more a cigarette or cigar is smoked the greater the concentration of carbon monoxide and other combustible substances in the stub, the reverse being the case in partially-smoked cigarettes

## NICOTINE

Nicotine is the largest and most important

I

k

of hemlock) and about equal to prussic acid in its lethal properties Symptoms of pure concentrated nicotine poisoning include irritation of the mouth and throat, salivation, headache, and dizziness At a later stage there is confusion, disturbed vision and hearing, coldness of the extremities, nausea, vomiting, and diarrhœa Respiration is quickened and breathing is difficult. The pulse-rate is raised and in the terminal stages the patient becomes unconscious and dies following convulsions

Nicotine is primarily a stimulant of the central nervous system, but at a later stage a depressant, acting on the ganglia of the sympathetic and parasympathetic systems.

The nicotine content of tobacco varies with such factors as seed, soil, fertilizer, and methods of harvesting and curing The temperature of the season also affects the percentage content, which may vary from 0 86 per cent to 2·5 per cent The nicotine content of tobacco is in no way related to the strength or expensiveness of the leaf It is important to note that nicotine is not entirely destroyed by burning, a large proportion going into the smoke on combustion. A much greater proportion of nicotine is destroyed when dry tobacco is smoked than moist In moist tobacco a higher percentage of nicotine is present in the smoke

## ABSORPTION OF TOBACCO BY-PRODUCTS INTO THE BODY

The absorption into the body of the main constituents of tobacco, mainly nicotine and carbon monoxide, takes place via two channels, namely, the mucous membranes of the mouth, nose, and throat, and the lungs

Absorption by the latter only occurs when smoke is inhaled, and the amounts absorbed are much greater, with demonstrable results on the various body systems Thus when inhalation does not take place about 60 per cent of the total nicotine content is absorbed, but when inhaled over 90 per cent is absorbed, or half as much again

## ELIMINATION OF TOBACCO BY-PRODUCTS FROM THE BODY

**1. Nicotine.**—A little more than 2 per cent of the total nicotine absorbed is excreted in the urine and a small quantity is detoxified

in the liver. Nicotine may be demonstrated in the breast milk of a nursing mother

**2. Carbon Monoxide.**—The elimination of carbon monoxide from the system is very slow and 1 to 3 per cent may be demonstrated in the blood 24 hours after smoking has ceased.

## CARBON MONOXIDE AND RESPIRATION

**1. General.**—Carbon monoxide is the poisonous constituent of coal gas, and in sufficient quantities produces illness and death from asphyxia It is present in small quantities in the combustible products of tobacco smoke, and is responsible for many of the symptoms of excessive smoking

**2. Effect on Oxygenation.**—Carbon monoxide reduces the oxygen-carrying capacity of the blood owing to the formation of carboxyhæmoglobin In addition there is increased retention of oxygen in the blood, with a consequent diminished supply to the tissues. The saturation of blood-hæmoglobin with carbon monoxide in smokers is shown below —

| | per cent |
|---|---|
| | 4 |
| | 5–10 |
| | 5–7 |
| | 21 |

In the last-mentioned case severe respiratory distress may be observed

## ALTITUDE TOLERANCE

Smoking reduces a person's altitude tolerance as shown by the following —

| *Actual Altitude, Non-smoker* | *Apparent Altitude, Smoker* |
|---|---|
| Ft | Ft |
| Sea level | 7,000 |
| 10,000 | 14,000 |
| 20,000 | 22,000 |

In addition to these figures all altitude tolerance tests indicate decreased efficiency in smokers

## EFFECT OF EXCESSIVE SMOKING ON THE GENERAL BODY SYSTEMS

**1. Respiratory System.**—There is increased tendency to coughs and colds, with irritation of the mucous membrane of the respiratory tract This irritation is brought about by several

factors, including the nicotine, ammonia, alkaloids, pyridine, and glycols present in tobacco smoke as well as the raised temperature of inhaled air In addition to the symptoms mentioned above, a chronic catarrhal discharge is often present which may lead to partial or complete blocking of the Eustachian tubes. This in its turn may lead to difficulty in adjusting pressures in the middle ear on descending from height.

**2. Cardiovascular System.**—Palpitations are common, cardiac pain less commonly so; pulse-rate and blood-pressure are raised and disturbances of rhythm are not uncommon There may be constriction of peripheral blood-vessels The effects on the cardiovascular system are caused by nicotine, which acts in the following ways —

*a* Directly on the heart and blood-vessels

*b* Through the sympathetic nervous system.

*c*. By the liberation of adrenaline, which results in general stimulation of the endocrine system.

These factors are transmitted *in utero* to the fœtus, resulting in an increased fœtal heart-rate.

Graybiel and others found that the T-wave of the electrocardiogram was inverted by smoking in some cases

**3. Gastro-intestinal System.**—There is increased salivation and decreased stomach motility.

**4. Central Nervous System.**—Although smoking has a calming [illegible] decreased [illegible] on of the [illegible]

**5. The Eye.**—Amblyopia and decrease in visual acuity is a common condition in heavy smokers caused by nicotine acting on the retinal nerve. The same condition has been observed in Australian horses which eat tobacco leaves as part of their normal diet Night vision is considerably reduced in smoking, because the rods, on which night visual acuity depends, are extremely sensitive to minor degrees of oxygen lack.

**6. The Ear.**—A number of cases are known of toxic neuritis of the auditory nerve but this only occurs in cases of extremely heavy addiction.

## CONCLUSIONS

It will be seen that the absorption of by-products of tobacco [illegible] varying severity [illegible] on to exercise, [illegible] s a result of smoking, and there is no doubt that a non-smoker is a fitter man

than one who smokes, although actuarial estimates of expectation of life do not put that of smokers very much lower than that of non-smokers

No alarm need be occasioned, however, by the degree to which smoking is indulged in at present by the majority of aircrew, because in a great many cases smoking is largely a social habit and inhalation is the exception rather than the rule Heavy or chain smoking is uncommon.

It is a matter, however, that requires watching to ensure that cases of heavy addiction do not produce disability in flying personnel

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# CHAPTER VIII

# SPEED AND ACCELERATION

## DEFINITIONS

VELOCITY may be defined as the distance travelled in a given direction in a unit of time, and can be expressed by the following formula:—

$$\text{Velocity} = \frac{\text{Metres}}{\text{Seconds}} \quad \text{or } V = \frac{M}{S}$$

There is adequate reason for the belief that there is no practical limit to the velocity that the human frame can withstand, provided that it is uniform in rate and direction. We are ourselves moving with a nearly uniform velocity of about 18 miles per second owing to the rotation of the earth around the sun, but because our relation with the earth is comparatively static, and our velocity nearly uniform, we are unaware of it.

The resistance of air increases as the square of the velocity of a body in relation to the air, and while it is known that at the threshold of the speed of sound certain turbulences of a dangerous nature are set up in relation to an aircraft, it has been shown that if the aircraft flies 'through' this threshold these turbulences diminish at ultrasonic speeds

Acceleration may be defined as rate of change of velocity, and the change may be either in the *magnitude* of the velocity, and the or in its *direction*, or in both When the direction of the motion remains unchanged, but the speed varies, we speak of *linear* acceleration. For convenience of reference an increase in velocity is frequently referred to as acceleration and a decrease in velocity as deceleration. Alternatively, the terms used are positive and negative acceleration Acceleration in various directions may be brought about in the following ways, among others · forwards in catapult or rocket-assisted take-offs; backwards in arrested or crash landings, downwards in a free fall with an unopened parachute, upwards when traversing turbulent air pockets; and laterally when horizontal forces act at right angles to the long axis of the aircraft.

Rocket-assisted propulsion introduces many practical acceleration problems,-and the effect of forces due to high acceleration assume greater importance as the performance figures for aircraft progress. It is necessary first to consider some of the laws of *physics concerning speed and acceleration in order to appreciate* how these forces arise.

Acceleration of a body requires the action of a force, and the force is equal to the mass of the body multiplied by the acceleration. Though it may not be at once obvious how large the acceleration is in the case of a body moving with constant speed in a curved path, *it is important to realize that large accelerations and hence* large forces may arise in such cases, the forces being larger the greater the speed and the greater the deviation from a straight path. It is forces of this kind that cause a car to skid when cornering at speed. Acceleration is usually expressed in 'g' units, one unit being equal to the acceleration of a freely falling body at the earth's surface (32 ft. per second, per second). In this case the force accelerating the body is equal to its own weight, so that if the same body is made to accelerate at a rate of A, expressed in 'g' units, then the force producing the acceleration must be A times its weight. The advantage of expressing A in these units is that it enables us to visualize the forces acting on the accelerated bodies by comparing them with the forces due to gravity, with which we are familiar.

**1. Linear Acceleration.**—This occurs during change of velocity in a straight line such as is experienced in parachute jumping, catapulting of aircraft, forced or arrested landings, rocket propulsion, and pilot ejection. *Table VIII* indicates terminal velocities attained with varying degrees of acceleration.

In order to estimate the forces necessary to produce uniform linear accelaerations, the following formula is used —

$$F = M \frac{V_2^2 - V_1^2}{2D}$$

where F = force in poundals (i.e., force in pounds × 32)
M = mass of body in pounds
$V_1$ = initial velocity in feet per second
$V_2$ = final velocity in feet per second
D = distance in feet over which acceleration takes place

The force per pound of the accelerated body is thus

$$F/M = \frac{V_2^2 - V_1^2}{2D}$$

and is equal to the acceleration in feet per second. If we divide both sides of this equation by 32 we obtain the force in

pounds per pound, which is equal to the acceleration in 'g' units.

$$A = \frac{V_2^2 - V_1^2}{64D} \text{ g}$$

Some of the more frequent occasions in flying when abnormal 'g' stresses may be encountered are as follows :—

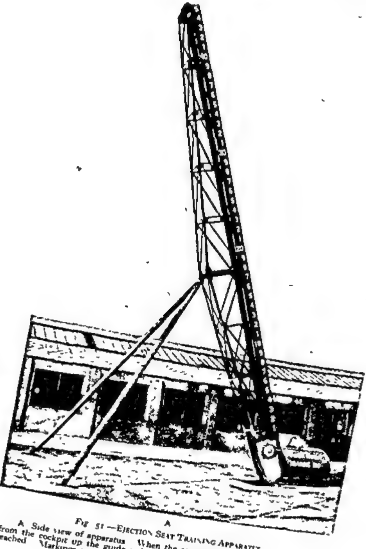
*a Parachuting* —Gravity produces an acceleration of 32 ft. per second, per second. Suppose a man were to jump from a height of 4000 ft. If there were no resistance (which condition could only exist in a vacuum) his speed would constantly increase, and he would reach the ground in about sixteen seconds, travelling at about 500 ft per second Since, however, air resistance increases as the square of the velocity, his falling speed increases only to

*Table VIII* —TERMINAL VELOCITIES ATTAINED WITH VARYING 'g' AND TIME FACTORS

| TIME | ACCELERATION (g) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | TERMINAL VELOCITY | | | | | | | | | |
| Secs | m p h | m p h | m p h | m p h | m p h | m p h | m p h | m p h | m p h | m p h |
| 1 | 22 | 44 | 66 | 88 | 110 | 132 | 154 | 176 | 198 | 220 |
| 2 | 44 | 88 | 132 | 176 | 220 | 263 | 308 | 351 | 395 | 439 |
| 3 | 66 | 132 | 198 | 263 | 329 | 395 | 462 | 527 | 593 | 659 |
| 4 | 88 | 176 | 263 | 351 | 439 | 527 | 615 | 703 | 791 | 878 |
| 5 | 110 | 220 | 329 | 439 | 549 | 658 | 768 | 878 | 988 | 1098 |
| 6 | 132 | 263 | 395 | 527 | 658 | 791 | 922 | 1052 | 1185 | 1318 |
| 7 | 154 | 308 | 462 | 615 | 768 | 922 | 1076 | 1229 | 1392 | 1537 |
| 8 | 176 | 351 | 527 | 703 | 878 | 1052 | 1229 | 1405 | 1580 | 1757 |
| 9 | 198 | 395 | 593 | 791 | 988 | 1185 | 1382 | 1580 | 1780 | 1975 |
| 10 | 220 | 439 | 659 | 878 | 1098 | 1318 | 1537 | 1757 | 1975 | 2197 |

the point where the air resistance equals the pull of gravity, when the velocity becomes constant at approximately 130 m p h or 190 ft per second It is important to realize that the constant speed of 190 ft per second would also be reached even though he were to jump from a plane diving towards the earth at a speed of 400 m p h Travelling at a velocity of 190 ft per second, it would take him about 20 seconds to reach the earth. If, however, the parachute is opened, his velocity is diminished to about 20 ft. per second, and he would then take about three and a half minutes to descend. The rate of deceleration from 190 ft per second to 20 ft per second is about 2–3 'g' units as a general rule. If the parachute is immediately opened on jumping from a plane travelling downwards or even horizontally at high speed (400 m p h. or more)

from a jet aircraft in flight. It is likely that with increasing
the wind pressures exerted on a pilot after ejection will b
great for safety, and to overcome this the pilot and his n
are ejected as a complete capsule, whereby he is protected

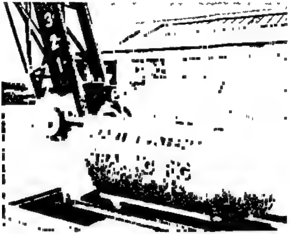


A

Fig 51 —EJECTION SEAT TRAINING APPARATUS

A Side view of apparatus When the cartridge is fired the pilot is ejected from the cockpit up the guide rails A latch retains him at the highest point reached Markings are in feet

cold, wind pressures, and sudden decompression At a lower altitude pilot and capsule separate and descend normally



B


C

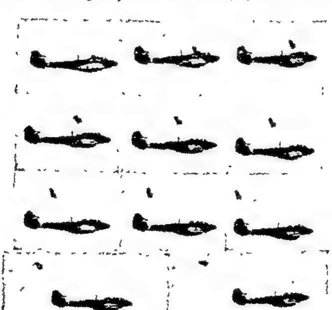
D


E

B The cockpit hood has been opened to the release position
C, The subject is grasping the firing control blind handle
D, Subject with the face screen nearly pulled taut and just on the point of firing
E The subject has just fired the cartridge and is being ejected from the cockpit Note the restraining effect of the blind into which the head is being firmly pressed as a result of the upward acceleration

*(By courtesy of Martin-Baker Aircraft Ltd)*

*e Rocket Propulsion*.—It is not likely that pure rocket propulsion for passenger aircraft will be used in the near future as other forms of propulsion such as pure jet and airscrew turbines will be more suitable, although rockets may be used for assistance at take-off. The amount of 'g' experienced on such occasions will be limited



by the factor of passenger comfort, and can be infinitely varied by the degree of charge which is inserted.

*f Pick-up from the Ground*.—Another example of the application of excessive forces of acceleration is where a person on the ground is picked up by an aircraft flying overhead, as was originally used in the case of agents in enemy-occupied territory. With suitable harness, no injury is experienced if the correct position is adopted on pick-up, namely, the back to the line of flight in a crouching position

with the head well bent forward The acceleration involves mo ment from rest to 120 m p h in the space of half a second, the over acceleration figures on such an occasion being 5–7 'g' in an upwa direction towards the head Many such pick-ups were achiev without injury to the persons concerned when these precautior were observed

Glider 'snatch' pick-up is now a recognized practice, and car be used for such susceptible persons as war casualties without fear of injury if proper precautions are observed, as described

**2. Centrifugal Force.**—When a body moves with constant speed round a circular path of radius R ft with velocity V ft per second, it may be shown to be accelerating towards the centre of the circle (which paradoxically it never reaches) at a rate $V^2/R$ ft per second, per second Thus the force in pounds per pound acting towards the centre necessary to constrain the body to move in the circle rather than to continue in a straight line is,

$$\frac{V^2}{32R}$$

which is also the acceleration in 'g' units

If V is expressed in miles per hour, the acceleration in 'g' units becomes

$$\frac{V^2}{15R}$$

Instead of saying that a certain force is necessary to constrain the body to move in a circle, we frequently say that the body exerts a 'centrifugal force' of the same magnitude

## EFFECTS OF ACCELERATION ON MAN

The majority of symptoms and the most interesting effects of acceleration are produced by changes in direction of an aircraft at high speeds Since the forces required for turning a machine act mainly on the wings, they are transmitted in a direction parallel to the long axis of the body of the aircrew seated in a normal attitude. The effects of acceleration on man will depend upon :—

1 The degree of acceleration
2. The time of action
3. The direction of the force in relation to the long axis of the body
4 The area and site over which the forces are applied

For a given time period, say 5 seconds, an acceleration equal to 3–4 'g' can be readily tolerated, whereas 10 'g' cannot be withstood as a general rule If, however, the time interval is shortened to one

second even 10 'g' may be readily withstood without the production of symptoms

In manœuvres during combat, practically all turns are made with the head of the pilot or occupants towards the centre of the orbit, with the feet, therefore, pointing in the opposite direction. Centrifugal force consequently acts towards the floor of the plane and parallel to the long axis of the body. The pilot, therefore, feels that he is being pressed into his seat.

When the centrifugal force is exerted in the direction of the long axis of the body the following symptoms may be experienced,

A B

*Fig* 53 —Change in shape of the heart during and immediately after exposure to positive accelerations Note the elongation of the left lateral border of the heart during the action of positive 'g' in A, and the return to a more normal shape in B (*Reproduced by courtesy of The Mayo Clinic, Rochester, U S A*)

depending on the amount of 'g' produced. At 2 'g' the subject is pressed firmly into the cockpit seat with a feeling of pressure on the buttocks, between 2 and 4 'g' there is sagging of the cheeks, difficulty in holding up the head, and increased difficulty in breathing due to downward traction of the diaphragm. In addition, at this stage there is an associated sagging of all thoracic and abdominal viscera (*Fig*. 53) and movement of the extremities becomes difficult or impossible

At 4–5 'g', lasting for more than 3 seconds, visual disturbances occur, the first of which consists of partial loss of vision or 'grey-out', when form becomes blurred and indistinct Lights can be seen but not accurately assessed or correlated This is followed by complete loss of vision or 'black-out' (*Fig*. 54).

At 5–6 'g' and above, for more than 3 seconds, consciousness is lost, followed in some cases by epileptiform convulsion. On recovery, which is very swift, there is a small degree of disorientation and confusion for a short time and occasionally slight residual headache. There are no after-effects.

The symptoms described may be explained by changes which occur in the circulatory system. The circulation may be regarded

2 'g'

4 'g'

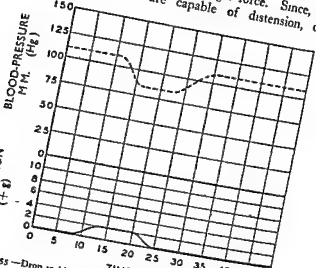
5 'g'

6 'g'

as a hydrostatic column, and in this connexion it will be remembered that hydrostatic pressure (P) equals the height of its column (H) times its density times 'g', or $P = H \times D \times$ 'g'. Thus at 1 'g' the hydrostatic pressure in a 5-ft. column of water is 2·1 lb. per sq. in. at the bottom. At 10 'g' therefore this becomes 21·0 lb. per sq. in. At 7 'g' the blood thus seems as heavy as iron, and at 13·5 'g' it exerts as much pressure as would mercury at rest.

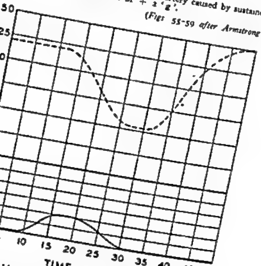
If the circulatory system were made up of a system of rigid pipes which could not dilate, circulation would not be interfered with

...ce of centrifugal force. Since, howev...
...eries and veins are capable of distension, dilatatio...




...55 —Drop in blood-pressure in carotid artery caused by sustained acceleration of + 2 'g'.

(*Figs* 55–59 *after Armstrong*)




...blood-pressure in carotid artery caused by sustained acceleration of + 4 'g'.

...increase in hydrostatic pressure Thus the
...ne lower portion of the circulatory system

increases, with a resulting drop of blood-pressure (*Figs.* 55–59) The blood is not returned to the right heart, and the heart

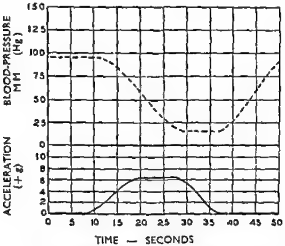



*Fig* 57.—Drop in blood-pressure in carotid artery caused by sustained acceleration of + 6·2 'g'

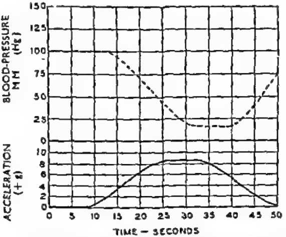



*Fig* 58.—Drop in blood-pressure in carotid artery caused by sustained acceleration of + 8·3 'g'

becomes virtually empty Circulation to the brain is markedly effected

The reason why 'greying-out' and 'blacking-out' occur at lower 'g' values than those which produce unconsciousness, is that the vitreous humour of the eye has an internal pressure of approximately 18 mm Hg. Therefore, the arteries supplying blood to the retina of the eye must overcome this 18 mm Hg. of counter-pressure before any blood enters the area. There is no such counter-pressure in the brain proper, however, and, in addition,

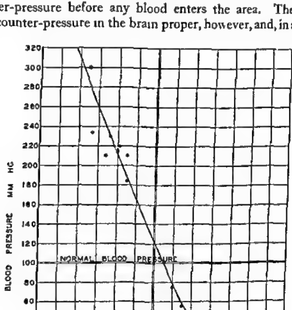



*Fig* 59—Composite curve showing changes in blood-pressure from various positive and negative accelerations

since the brain is encased in a rigid cranium, the blood-pressure required to supply it is assisted by a negative pressure of 10 cm of water due to syphoning effect. The eye, being extracranial, is not affected by this action; hence when centrifugal force is applied, a point is eventually reached when the blood-pressure can maintain the circulation in the brain but is unable to maintain *circulation to the retina, and vision is lost* while consciousness remains

The circulation reacts to a drop of blood-pressure, first by an increase in the pulse-rate (*Fig.* 60) and secondly by vasoconstriction due to the carotid sinus and aortic arch reflexes If these reflex

responses are rapid and powerful enough, a transitory greying period may result, with subsequent restoration of vision even though the centrifugal force is maintained.

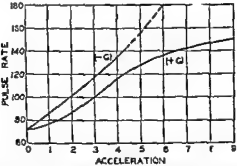



*Fig 60*.—The average increase in pulse-rate produced by various sustained positive and negative accelerations

## METHODS OF STUDYING THE EFFECTS OF CENTRIFUGAL FORCE ON MAN

The effects of centrifugal force on man can be studied by two methods These are observations made in an aircraft during flight, or by the use of the centrifuge, or accelerator, or other mechanical means. The first method has certain disadvantages, for among other things it is dependent on the weather and the ability of the pilot to perform a given manœuvre in precisely the same way time and time again There is the added fact that any observer will also be under the influence of the same centrifugal force as the subject.

The centrifuge, on the other hand, is free from these objectionable points, but has one disadvantage in that a marked angular acceleration is necessary to produce the required centrifugal force. Suppose that a force equal to 5 'g' is attained at a speed of 30 revolutions per minute This means that the centrifuge must start from rest, and reach this speed of rotation in a short time If this time is equal to 5 seconds, then the angular acceleration must equal 36° per second per second, so that in the first second, 36° are turned; in the second 72, and so on until by the fifth second the machine is turning at the rate of 180°/sec. or 30 r p m A plane travelling at 400 m p h, on the other had, may develop a force of '5 g' by simply changing its direction This must be considered in the studies on the centrifuge in connexion with symptoms of vertigo which occasionally arise

The effects on man as produced in the centrifuge have been borne out in actual flying experience, where similar acceleration figures have been demonstrated by pilots with closely similar results. It will thus be seen that whilst not producing exact reproduction of linear accelerations, the centrifuge provides a very satisfactory

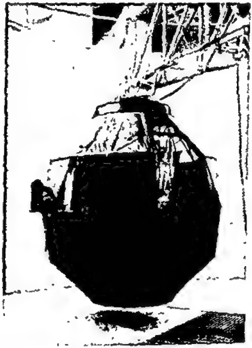


Fig 61.—Centrifugal accelerometer Cockpit The wall and floor of the well can be seen in the background, the revolving arm, from which the cockpit is suspended, above.
*(Figs 61–65 by courtesy of W R Franks, Esq )*

method of experimentation, and the results obtained have been most instructive

A typical apparatus consists of a small cabin, similar to an aircraft cockpit, in which the subject is strapped, with normal aircraft controls to hand This cabin is suspended at the end of an arm 30 ft long, revolving around a central pillar, in an observation well 70 ft. in diameter A controller sits in the centre, regulating the degree of 'g' which can be applied and observing the subject's reactions Details of the apparatus and recordings are shown in *Figs. 61–64*

In front of the pilot, in place of normal aircraft instruments, is a series of lights, and on the control column is a corresponding

Fig 62 —Centrifugal accelerometer Close-up of cockpit interior

Fig 63 —Centrifugal accelerometer Recording apparatus

series of buttons. Similarly connected to the earphones in his helmet is a buzzer to which he is instructed to respond on receiving certain signals

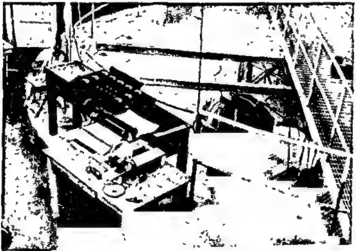


*Fig* 64 —Centrifugal accelerometer General view of well and controls

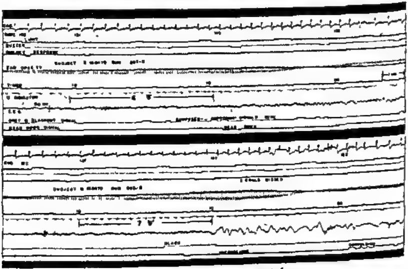


*Fig* 65 —Specimen recording on centrifuge

While the centrifuge is in action the controller transmits visual and auditory signals and according to the replies received can judge whether the subject can observe light flashes or hear the buzzer.

At the time of the test, readings of respiration and blood-pressure are recorded, and electrocardiograms and electro-encephalograms are taken. In addition a ciné camera takes a colour film of the objective changes which take place. A representative reading is shown in *Fig.* 65, and a series of photographs of a person being subjected to centrifugal force in *Fig.* 54 (p. 111).

## OBJECTIVE RESULTS OF STUDIES

There are no significant electrocardiographic or electro-encephalographic changes. The blood-pressure drops and there is a transient rise in pulse- and respiration-rate to begin with, but subsequently the pulse-rate increases in proportion to the amount of acceleration. At 4–5 'g' the respiration becomes forced and irregular, and stops altogether due to downward traction of the diaphragm at 5–6 'g'. Following on a blanching of the face and sagging of the tissues, at an early stage, the patient becomes unconscious and in some cases this is followed by epileptiform convulsions. These start with a twitching of the face, which rapidly increases to convulsive movements of the arms and legs. Recovery is swift and complete. The cause of these convulsions is probably due to the cerebral anæmia incurred and occurs more frequently in the centrifuge than in actual flying. At one time it was thought to be due to trauma of the base of the brain, but this was disproved by the fact that greater 'g' stresses on that area are brought about by the simple act of jumping down from a small height without the occurrence of symptoms of such damage. This factor of epileptiform convulsions is of some importance in that it presents a possible explanation of some cases of a specialized type of accident in which aircraft, when beginning to come out of a terminal velocity or other high-speed dive, perform a violent aerobatic manœuvre and either disintegrate in mid-air, or fly into the ground. It has been postulated that these convulsions may occur as the centrifugal force increases when the pilot attempts to pull out of such a manœuvre. As a result of the convulsions the pilot pulls the control column back still farther, or applies violent rudder, which either induces this specialized form of stall, or causes the aircraft to disintegrate.

## CENTRIFUGAL ACCELERATION WITH THE SUBJECT INVERTED

Such conditions are seldom encountered in aircraft except in extreme aerobatic or combat manœuvres and the symptoms experienced have not assumed great importance in operational flying.

The objective symptoms under such conditions are as follows. The face is markedly red and congested There are numerous small petechial hæmorrhages, the eyes are congested, and the conjunctival vessels become prominent. The respiration-rate increases and there is severe mental upset similar to that produced in cerebral concussion. The blood-pressure rises and the cardiac sphincter fails Subjective symptoms include congestion of the face, and discomfort, due to the upward displacement of the abdominal and thoracic organs As 'g' increases there are increased pressure symptoms in the head and face, including severe headache, pain and throbbing in the eyes, mental confusion, and the phenomenon known as 'red-out', in which there is suffusion of all the objects seen with a bright red coloration

## TRANSVERSE ACCELERATION

Much greater stresses can be taken in the transverse plane than the longitudinal, and if the forces due to acceleration act through the transverse axis of the body they can be withstood much more rapidly and for longer periods. Thus 12 'g' can be tolerated for approximately 15 seconds, after which breathing becomes difficult. Symptoms other than these do not occur.

Transverse accelerations do not affect the circulation to the same extent as longitudinal ones, owing to the fact that the main blood-vessels of the body are in the long axis of the body.

## PREVENTION OF EFFECTS OF 'g'

**1. Reduction of Black-out Threshold.**—From the foregoing it follows that methods of preventing 'black-out' in flying must be directed towards —

*a* Decreasing the degree of centrifugal force

*b* Decreasing the action time

*c* Preventing pooling of the blood in dependent parts of the body

*d* Decreasing the height of the hydrostatic column

*e* Changing the direction of the force from the longitudinal to the horizontal axis of the body

These results can be achieved in a variety of ways —

*a Control of Turns at Speed*—*Since the degree of* acceleration is proportional to the square of the velocity and varies inversely as the radius, the degree of centrifugal force may be diminished by either decreasing the speed or increasing the radius Thus at 400 m p h a turn with a radius of 1600 ft develops 6 5 'g', but

with a radius of 3000 ft. only 3·5 'g' will result If, however, with a constant radius, 4 'g' is developed at a speed of 200 m p h, then at 400 m p h. 16 'g' would result

*b. Limitation of Time*.—This is largely under the control of pilots at all times, and many of them when experienced become

Fig 66

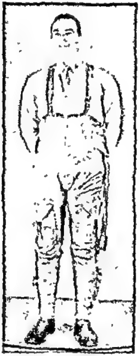


Fig 67

Figs 66, 67.—Types of anti-'g' pressure suits (*By courtesy of The Berger Brothers Co*)

adept at limiting their turns or manœuvres according to their known 'g' limitations

*c. Pre*[illegible]

[illegible]

[illegible]

pressure, provide increased 'g' tolerance Such suits are, however, restrictive to the wearer, and except for particular flights have not been universally adopted other than for fighter pilots, for whom they are very successful. An increased 'g' tolerance of 2–4 'g' can be attained by such a method. A further advantage

of pressure suits is that when worn by pilots who are frequently subjecting themselves to minor degrees of 'g' stress, the incidence of fatigue is greatly lessened, with a coincident increase in efficiency. The value of such an accessory in combat is obvious. Illustrations of equipment of this sort are shown in *Figs* 66–68

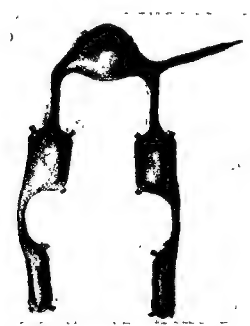


*Fig* 68 —Inflatable bladders for insertion in anti-'g' suits

*d. Posture.*—An alternative method is for the aviator to adopt a crouching position, sometimes almost prone. Pilots using the crouching position can increase their tolerance by 2 'g' or more (*Fig* 69) This method has been used to a limited extent, but the accompanying difficulties inherent in the system, such as restricted vision, awkwardness of control, cockpit layout, and discomfort, at present outweigh the advantages obtained It can be seen from *Fig.* 69 that the crouching position reduces the weight of the hydrostatic column by over 46 per cent.

**2. Prevention of Accidents as a Result of Excessive 'g'.**—When violent deceleration occurs, as in an accident, the occupants of an aircraft would be thrown violently forward, with consequent injury, if measures were not taken to retain them in their seats This usually takes the form of some retentive belt or harness

*a Retaining Harness and Belts*—The most usual form of passenger safety harness consists of a broad strap attached on either side of the seat at, or near, the angle between the back and the seat proper, the ends being secured across the passenger's hips and lower abdomen. A simple locking device is usually incorporated which can easily be undone in an emergency. Even so, in the midst of the probable confusion which results on such an occasion, passengers are liable to forget even this simple piece of mechanism,

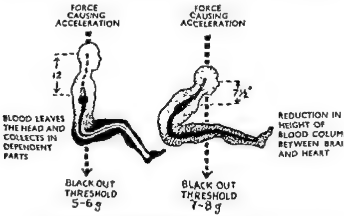



*Fig* 69 —Blacking-out problem in aircraft Diagram showing how positioning of the body affects the threshold for blacking-out

(*Figs* 69 70 *from* '*Preventive Medicine in the Royal Air Force*', *by kind permission of Air Marshal H E Whittingham*)

and after an accident crew members should be on the look-out for trapped personnel

This type of retaining equipment has two distinct disadvantages First, if violent deceleration occurs, as may be experienced in an accident, passengers may be subjected to the 'jack-knife' effect in which the upper part of the trunk is thrown violently forward, with possible serious injury to the head, due to striking some hard object Secondly, there may be severe injury to the abdominal organs, particularly the bladder, when sudden, violent retentive forces are applied as would occur in such circumstances Thirdly, damage to the lumbar spine may occur (*see Fig* 70)

Such an eventuality can largely be prevented by using a type of harness similar to that used in military aircraft, in which the retentive straps, four in number, are so arranged that two pass over the shoulders directly from behind, and *two over the pelvis, all four* being attached to a quick-release buckle over the abdomen Thus

the 'jack-knife' effect is prevented. Even under such circumstances, however, *there may be a forward dislocation* of the cervical vertebræ if the head is unsupported (*Fig.* 70). Cumbersome and complicated harness is unpopular with the travelling public, however, and should be avoided whenever possible. Were it not for the safety factor involved, many airlines would like to do away with retentive apparatus altogether.

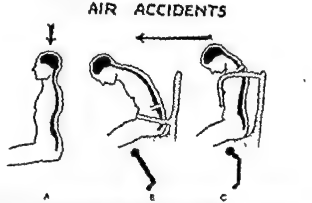



*Fig.* 70.—Diagrammatic representation of crash fractures of spine. A, Compression fracture as may occur on heavy landing by parachute. B, Dorso-lumbar flexion fracture of spine in aircraft when wearing lap-type safety belt. Note also position of head, which might strike an object in front, causing fracture to skull. C, Cervicodorsal flexion fracture of spine when wearing shoulder-type safety harness.

*b. Backward Facing Seats.*—Undoubtedly the surest protection against injuries under such conditions is the provision of backward-facing seats with high backs, in which the head is fully *supported, but this arrangement has undesirable psychological* disadvantages, in that many persons object to being instructed which way they should sit, and, in fact, prefer, whether by habit, perversity, or personal taste, to sit facing the way they are travelling. It is an established fact that injury to passengers in the event of violent deceleration as occurs in a crash can be considerably minimized by adopting a rearward facing position (*Fig.* 71). *Very much greater 'g' stresses can be taken in this* way, and striking examples have been afforded where an individual has adopted this position in a crash and has escaped injury when other occupants were killed or severely injured. Whittingham ... the ideal posture during ... legs flexed, ... wards the rear of the fuselage. de Haven, Denny-Brown, and Russel have shown that a very high force of deceleration (up to 300 'g')

is necessary to cause concussion if the head is not actually struck. While this is correct from a purely anatomical and physiological point of view there are certain other points which are open to question, particularly where the transport of fare-paying passengers is concerned. In a commercial company the physical and mental comfort of passengers is an important consideration and all aspects of the question must be given equal weight when deciding such a question. Firstly, a passenger's reaction to having to sit facing backwards is frequently more adverse than is often assumed.

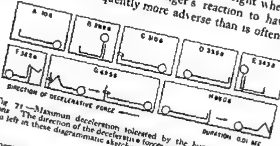



Fig. 71.—Maximum deceleration tolerated by the human body in various positions. The direction of the decelerative forces imposed on the subjects is from right to left in these diagrammatic sketches. (*After McFarland.*)

The analogy which is often used to seating arrangements in trains and other forms of public transport is not quite a true one because in such cases a passenger is not compelled to face backwards, but can face whichever way he pleases. It is, in fact, true that a great number of people hold the strongest views on travelling 'facing the engine'. Whether their views in this respect are justified or not is not the point. The fact is they like it, and think it is better for their health and bodily comfort; passenger-carrying companies have got to cater for such views, when the public is their source of revenue, and continued existence. In civil flying one is denied the advantages (or otherwise) in military flying whereby orders can be issued and will be obeyed without question, and very serious consideration has to be given to any measure which interferes with the freedom of the individual more than absolutely necessary. Secondly, accident consciousness is a more important point than is sometimes realized. That is to say, while at no time neglecting the possibility of accidents, and taking all reasonable precautions to minimize the results, the general attitude which it is desirable to engender among passengers is the inherent safety in flying, and to do all that is humanly possible to dissociate passengers' thoughts from the possibility of increased hazards in this form of transport. Flying as a method of carrying out a journey is still a novelty to a vast proportion of the travelling public, who look upon it as something of an adventure, and anything which can help to add to

the normality of the occasion is to be encouraged Even experienced air travellers sometimes admit to a subconscious (in fact almost unconscious) tension when flying, particularly over long stretches of water such as the greater oceans. If a passenger asks why all the seats are facing backwards, and is told that this is to lessen his injury in the event of a crash, any dormant fears which he may have in this respect may be immediately brought to the surface, and an unfavourable atmosphere be created.

The ideal solution may be swivel seats which can face in any direction, but which can be locked in the aft-facing position in a few seconds in the event of an emergency, but the installation of the necessary swivelling equipment constitutes a serious weight penalty—an ever-present problem in commercial flying Care would have to be taken that the seats gave full support to the back of the head and neck as there is nearly as great a chance of dislocation of the cervical vertebræ, if unsupported, in one position as the other

Finally it should be emphasized that all such considerations are useless unless seats are fixed to the floor of the aircraft sufficiently strongly to withstand the 'g' forces likely to be experienced in a crash Precautionary measures for the protection of the occupants of seats are worse than useless if, when an aircraft crashes, seats and occupants leave the floor and are precipitated against a bulkhead or other obstruction Modern aircraft seats should be stressed to withstand 20–25 'g' in a fore and aft direction

*c Conversion.*—Among some of the more interesting experiments in connection with deceleration is that which attempts to convert linear motion into circular motion. The conversion from one to the other decreases the force of 'g' acting upon a body, by changing the direction of the forces involved, and with this in mind experiments have been conducted with the cockpit as a completely separate circular unit within the aircraft, which becomes detached on the action of a crash, when the forward motion of the aircraft is converted, at the moment of sudden arrest, into a rolling motion

Crashes have been conducted with aircraft hitting the ground at speeds of over 100 m p h, the cockpit rolling free and the pilot being uninjured In these cases the effective 'g' experienced by the pilot amounts to not much more than 9 or 10 'g' for one second. Its application to large transport aircraft, however, is not practicable

## *FACTORS AFFECTING 'g' TOLERANCE*

Experience has shown that tolerance to high degrees of acceleration is decreased by fatigue, excesses in smoking or alcohol, anoxia,

inadequate sleep, or any debilitating condition. Various drugs have been tried with a view to increasing 'g' tolerance, but conclusive results have not been reached. Increased resistance to 'g' stresses can be obtained by the methods indicated in previous paragraphs. The greater the speed of modern aircraft, the greater will be the 'g' stresses set up in a turn, or when it traverses an air pocket or bump, although in the latter the stresses will probably only be of very short duration. Active research is therefore desirable from the civil as well as the military point of view, in order that discomfort or danger to passengers as well as aircrew may be prevented by suitable methods.

No conclusive evidence has been shown as to what subjects can stand the greatest forces of 'g', and individuals vary through the widest possible ranges. Some experienced fighter pilots tested have a very low 'g' threshold, whereas some ground crew, who have never flown, have relatively high values. It is found, however, that a non-athletic person is better able to withstand acceleration than an athletic one. The reason postulated for this is that in the latter the vascular bed is more relaxed, which allows a more easy shift in the blood. Statistics on this subject are as yet incomplete, but broadly speaking it may be said that 3 'g' is perfectly comfortable for passengers. This is the equivalent of 100 ft. gain per second. With this moderate degree of acceleration from rest the velocity at the end of only ten seconds would be 659 miles per hour (*See Table* VIII, p. 104). It will thus be seen that from the point of view of 'g' tolerance there should be practically no restrictions on aircraft performance in the foreseeable future on account of limitations of the human frame.

## COMMENTS AND CONCLUSION

There is a time lag of about 3 seconds between the terminal velocity or highest application of 'g' and actual 'black-out', so that a pilot can see perfectly at the terminal point of a power dive, and does not black out until he is climbing again. This is illustrated in *Fig.* 72.

An interesting feature of these changes is that with reduction of 'g' immediate recovery takes place and the subject can resume his normal functions efficiently with a clear brain. Thus all fighter pilots have come to regard 'black-out' as the normal accompaniment of sharp turns or dives, and many can be experienced during one flight with no permanent after-effects, although recent investigations have shown that frequently repeated accelerations of 2½–3 'g' cause systemic effects of which fatigue is the major

symptom This syndrome is increased by such factors as unsuitable aerodynamic properties or design of the aircraft used. The effects of excessive 'g' over short periods have not had an appreciable effect on the activities of such pilots, although some accidents

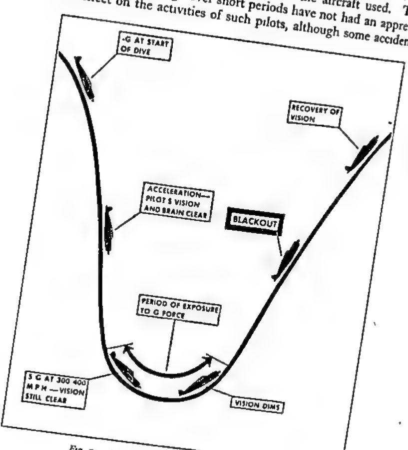



*Fig* 72 —Black-out occurring in flying manœuvres.

which have occurred in the past are probably due to such causes as have been described Increase in 'g' tolerance can be effected by various means, but it should be remembered that it is important to have full protection against the lower values of centrifugal acceleration as well as to prevent the effects of higher ones

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## CHAPTER IX

# EQUILIBRIUM

## HUMAN EQUILIBRIUM

HUMAN equilibrium in association with flying may be defined as the orientation of the aircraft in space by the pilot It does not refer to the relative position of the pilot in the aircraft.

Armstrong defines aerial orientation in wide terms as a pilot's awareness of geographical position, his relation to other aircraft or objects in space, or his reaction to gravity. Thus a pilot will know over what country he is flying, what his position is in a formation, and whether he is climbing, diving, or turning While the sensory impressions contributing to a man's equilibrium are similar on the ground and in the air, the proportion in which the various stimuli act is different for the reasons given below In order of priority these factors are as follows :—

1. **Vision.**—This is unquestionably the most important single factor in the maintenance of equilibrium, and if this sense is absent or deficient there is an immediate, grave, lowering of equilibrium sense Firstly, it is essential inside the cockpit for the reading of instruments and the correct manipulation of the aircraft controls Secondly, it is required for orientation and spatial assessment outside the aircraft A pilot judges the aircraft's flying attitude by reference to the horizon, or its attitude *vis-a-vis* the ground when approaching to land by computation of the angle of descent Distance from other aircraft in the air, and relative speeds and angles of approach, can all be judged by external observation, in many cases made more accurate of interpretation by experience. It must be realized, however, that at great heights speeds appear relatively slow, and the greater the distance between the aircraft and the earth the less the accuracy of visual perception and spatial assessment It is, therefore, necessary that a pilot relies on his instruments for flying an exact course on a level keel rather than by reference to the ground, which method is highly inaccurate at height

2 **Vestibular Apparatus.**—Studies on the importance of this organ with regard to equilibrium have been pursued for many

years, and at one time the theory was held that the labyrinthine organ was the primary and all-essential organ of orientation (*see Figs.* 73, 74), but recent work has shown that although it plays a very important part it is not the complete picture. The threshold of angular acceleration required to stimulate the vestibular apparatus in humans has been variably estimated to be about 0·2 degrees per second, per second (Tumarkin), and 2–3 degrees per second, per second, acting from 14 to 16 seconds (Mach). The threshold for vertical accelerations has been found to be between 4 cm. and 12 cm. per second, per second, (Bourdon) and for horizontal accelerations between 2 cm. and 20 cm. per second, per second (Kunze).

**3. Deep Sensibility (Visceral and Splanchnic Sense).**—These sensations have assumed increasing importance in certain circumstances described in detail elsewhere; at the same time they are unreliable and at times dangerous if relied upon to too great an extent by the pilot, owing to the fact that when flying normally there is a uniform action of gravity but when diving, spinning, turning, or climbing steeply, excessive 'g' stimulation occurs, producing a false stimulus to these organs.

**4. Tactile Sense.**—Somatic impressions and tactile sense are relatively unreliable for the same reason as the factors referred to in the preceding paragraph. Furthermore, in aircraft all the senses are so over-stimulated that confusion may frequently result. This is partly because the vestibular apparatus cannot, in the air, distinguish between centrifugal force and gravity, because these forces are fused as a resultant, the direction of which in relation to the earth's surface cannot be recognized if no horizon is in sight. Furthermore, the organs of equilibrium do not sense velocity, but only acceleration, whether in straight lines or in curves.

Many subjects whose occupation or physical characteristics might throw light on the matter, have been experimented upon, the more important being:—

1. Normal people.
2. Deaf mutes lacking vestibular perception.
3. Tabetics with impaired deep sensibility.
4. Deaf mutes with subnormal vestibular perception.
5. Ballet dancers, whose work includes large numbers of whirls and gyrations.

Armstrong quotes the results of these investigations as leading to the following conclusions:—

*a.* Normal persons are more accurate than deaf mutes in perceiving changes of attitude of an aircraft or sudden changes in vertical or rotary motion such as occur in spinning or deceleration.

*b.* Professional ballet dancers find that the only method whereby they can avoid becoming dizzy and nauseated when carrying out complicated and sustained successions of gyrations is by jerky movements of the head whereby they can momentarily fix their eyes on some object.

*c.* Muscle, joint, and tendon sense, splanchnic and visceral sense, and tactile and deep sensibility all play their part in producing the general impression of motion in space, but neither individually nor collectively are they capable of accurate aerial orientation.

## ILLUSORY SENSATIONS

The sense organs are frequently a source of false sensations in regard to position or movement, which, under certain circumstances, on account of their convincing quality and the reliance placed in them, may shake a pilot's belief in his instruments, leading to false reactions, with consequent dangerous results Such sensations can be very powerful, and may vitally affect air safety. With increasing speeds of aircraft, and consequent higher acceleration figures experienced, the problems may become of even greater importance than at present

Three of the more important of these illusions are as follows :—

1. The *autokinetic* illusion is solely a visual one and consists of the apparent movement of an object such as a light when fixated against a uniformly dark background, when other visual aids are lacking Vinacke states that this form of illusion is probably experienced at some time by all normal persons and that there is a short delay before onset, that is, between fixation and apparent movement of the object Movement is reported in about 50 per cent of subjects and varies in speed and direction The average duration is about 10 seconds, and voluntary control is slight. All these findings emphasize the dangerous nature of the illusion as far as pilots are concerned, for a false perception of movement of even a very few seconds is potentially fatal, should it lead the pilot into, say, a spin Graybiel and Clark further show that the illusory effect is abolished only with difficulty, even when an effort is made to improve spatial localization of objects, by rapid relative movement of the target or by periodically shifting the eyes about

The exact cause is not established with certainty, but is thought by some to be analogous to the eye movements of young babies or miners, who have been kept for long periods in the dark, and whose maculæ, inadequately stimulated under such conditions of low illumination, search from side to side in an effort to obtain sufficient stimulation for macula fixation.

Others postulate that it is similar to the 'streaming phenomena' which can be noted with a subject who after being in bright daylight suddenly enters a darkened room It is thought to be due to the movement of granular bodies in the retinal lymph-stream and is one of the entopic phenomena It is also thought that a psychological element is present

Graybiel and Clark approach the subject from the reverse aspect and suggest that it may be natural for man to perceive all objects as being in motion, and that in reality an explanation is required as to why fixed objects are in fact regarded as stationary. It has been proved experimentally that the eye and head cannot move by more than one or two degrees (Farree), but at the same time the head and eyes cannot be held motionless It is evident from the various theories presented that physical, physiological, and psychological factors all play a part

2 The *oculogyral* illusion is caused by a combination of visual and non-visual factors, namely, conflicting impulses received from the eye and semicircular canals respectively It consists of the apparent movement of objects resulting from stimulation of the semicircular canals following angular acceleration Thus a stationary object appears to move in a direction opposite to that of rotation It may be complicated by autokinesis, and aviators who are frequently subject to small angular accelerations such as occur when turning or banking in flight are ideal subjects for this type of illusion, particularly at night In particular cases the condition produces an apparent rotation of a light target around a central axis

3 A third type, known as the *oculogravic* illusion, is caused by a conflict of impressions between the eyes and the otolith organs It consists of the apparent displacement of an object in space as a result of stimulation of the otolith organs by acceleration Experiments conducted with a fixed light in an aircraft in complete darkness observed under different degrees of acceleration indicate that such illusions of motion and displacement occur between 10° and 60° of bank and increase with increasing bank They always occur during banks of 40° or more Roxburgh states that from the practical point of view the importance of these observations is the change in resultant 'g' when an aircraft accelerates under its own power This effect will become more important as aircraft power/weight ratios increase In conditions of bad visibility or at night the following sequence of events might occur. An aircraft is cruising straight and level, when the throttle is opened and the aircraft accelerates; the resultant 'g' force moves backwards, and the pilot feels he is climbing He therefore pushes the control column forward and may fly into the ground The acceleration

possessed even by present-day aircraft is sufficient to cause an illusion, in resultant 'g', of several degrees, and may be the cause of night accidents in experienced pilots. Presumably the danger *can best be avoided by strict attention* to aircraft instruments, assuming these to be free of acceleration errors. With higher thrust/weight ratios, linear accelerations will increase so that a pilot's change of 'plumb line' on opening the throttle may lead to disorientation, particularly in poor visibility.

The illusions described are very little reduced by habituation, which makes them all the more dangerous. They can be counteracted by absolute reliance on instruments and in addition they may be largely prevented, or cut short, by several methods all of which aim at spatial localization and correlation of light stimuli seen.

Firstly the presence of lights in different vertical and horizontal planes is almost completely successful in abolishing the condition. Thus when only the tail light of an aircraft is visible autokinesis *may occur, but if lights in different locations, such* as wing tips, nose, and tail, are used the condition is abolished.

Secondly, interruption of vision will eliminate the condition, and for this reason flashing lights are to be preferred to steady ones. Alternatively, the pilot may interrupt steady fixation by blinking.

Thirdly, localization by means of other lights on the ground largely prevents the onset of the condition.

Lastly, fixation on some other point such as a windshield frame or canopy helps in reducing the intensity of the illusion, although it is not entirely abolished in this way. In all cases there *will* be a conflict of sensations and emotions, in which it is vital, in the interests of safety, that the correct ones predominate and the illusory ones are eliminated. The illusions are potentially present all the time and may predominate in an emotional crisis, or when fatigue is present.

A pilot's training teaches him to subordinate these powerful impulses and rely entirely on his instruments, but as in all cases where training involves the disregard of physiological stimuli, anything which tends to reduce a person's physiological efficiency at the same time reduces his power of subordinating these impulses. Thus a pilot who is suffering from fatigue, lack of oxygen, or adverse psychological disturbances, may find that he is obeying his impulses rather than his training, with the result that reactions are produced whcih are instinctive and natural rather than voluntary and conditioned. The result of any of these may be disastrous so far as the control of an aircraft is concerned. In

addition to these, there may be a number of sensory illusions, brought about by conflicting impressions transmitted by various organs which may, if allowed, influence the action taken by a pilot, with the result that incorrect manipulative procedure may occur, resulting in an accident

Von Diringshofen has described the following disturbing deceptions of sensation produced with regard to the position and movement of an aircraft, when flying by means of instruments (i e, not using terrestrial observation), through faulty impressions gained from the human equilibrating mechanisms These illusions often have a convincing distinctness, because the position of the eyeballs is controlled by the mechanism for equilibrium, and owing to their forced motion convey illusions in regard to the motion of the aircraft The more important ones are as follows —

*a A Feeling of Climbing whilst in a Turn* —In carrying out an unnecessarily steep turn in blind flight the additional strain on the body due to the centrifugal force may produce the sensation of ascent The angle of bank of the aircraft is sensed as a position of ascent, and also seen as such This sensation gradually disappears if the turn is constantly maintained for a longer period

*b A Feeling of Sinking whilst coming out of a Turn* —The change to level flight from an unnecessarily steep turn may lead to a feeling of less-than-normal weight owing to the removal of centrifugal force, and hence a feeling that the aircraft is sinking. This feeling is the more marked the greater the stress produced by the centrifugal force, for example, when flying in a close spiral, and may lead to a very disagreeable feeling of falling, even when the flight has been carried out with the earth in sight and the aircraft has finally been levelled out It may be so marked that only strict attention to instruments and calm logical thinking will remove the illusion

If an excessively steep turn flown blind has ended, the reduction of the angle of bank may be sensed as ' pressure ' and the position of the aircraft may be regarded as that of losing height, although the machine is in reality flying horizontally This is because the impulses proceeding from the centre of equilibrium to the eyes have caused them to turn If a pilot in the clouds depends solely on his sensations he will usually tend to underrate the steepness of his turns, and consequently turn too steeply On straightening out to horizontal flying he will have a tendency to over-correct the aircraft if the change in the angle of the machine leads him to believe that he is descending, or he will ease back the control column if the sensation of falling seems to him to be strong.

*c A Feeling of a Lateral Tilt in the Opposite Direction to which a Turn is being made* —In a perfect turn, when the ground or the

horizon cannot be seen, the angle of bank cannot be sensed because the resultant of gravity and centrifugal force must fall at right angles to the transverse axis In blind flying the deviation of the resultant and, with it, of the angle-of-turn indicator may be sensed as an inclination of the aircraft to the side of the deviation

If in blind flight the aircraft skids during a turn on account of not having been given adequate bank, then the resultant no longer falls at right angles to the transverse axis. Thus the sensation is that of a tilt of the aircraft opposed to the true one These sensory illusions in regard to the transverse plane may even arise in blind flight flown absolutely in accordance with instructions.

*d. A Visual Impression of Lateral Instability when there is No Horizon by which to judge one's Relative Position in Space (i e, when flying between Two Clouds with Divergently Tilted Surfaces)*—The sensation of the aircraft being tilted when flying between two layers of cloud which are inclined to the horizontal, and with no visible horizon, is at times so convincing that the flyer begins to have doubts of the accuracy of his instruments and must, by hard thinking, overcome this false appreciation of the attitude of the machine. The cause of this illusion is due to the eyes having such an important role in the estimation of position, the sloping cloud layers being falsely regarded as a true horizon

*e. A Feeling of Turning during Straight and Level Flight.*—The most disturbing effect in blind flying is the sensation of turning which occurs even during flying horizontally or during the most perfect turn and may produce the illusion of rotation about all three axes. This illusion of rotation is particularly convincing in blind flying because of the working together of the eyes with the organ of equilibrium in the ear, which is failing to give the correct picture, thus leading to the impression of turning being not only felt, but seen This is probably the most important contribution to the explanation of the astonishing and suddenly occurring cases of dizziness of pilots during blind flying. Such illusions of turning arise especially on account of the numberless small disturbances of an aircraft about its three axes, particularly when the flight is made in bumpy air with an unstable machine. All the accompanying sensations are worked upon by the inner ear to produce false and disturbing sensations of rotation In part these rotations are sensed, and in part they do not come to consciousness As the sensations of turning which are sensed overlap each other and other sensations are added, a qualitative and quantitative estimate of movements is finally made which is quite false. Such illusions of rotation may also arise when the aircraft is in horizontal flight, as, for example, when, on account of airscrew torque the machine

deviates slowly and unnoticed from its course, and is then pulled back again by small movements of the rudder.

The physiological cause for these illusions lies in the currents in the fluid of the semicircular canals of the ear. The fluid, during the slow phase of turning, is carried with the movement of the canals themselves, but in the fast phase (when the correction is made) the fluid lags behind the movement, on account of its

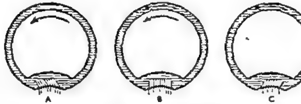


Fig 73.—Diagrammatic illustrations of action of semicircular canals. A Position at commencement of turn to left. B Position during rotation. C, Position after rotation has ceased. (*After H. von Diringshofen*.)


Fig 74.—Diagram of the semicircular canals. It will be seen that each canal lies in a plane at right angles to the others. (*After H. von Diringshofen*.)

inertia. The sensory hairs are thus affected only by the movement in one direction and thus set up the sensation of a continuous rotation (*Fig* 73).

*f. A Feeling of Diving when Turning.*—During blind flying, when an unduly sharp turn is made, a movement of the head leads to the illusory feeling that the aircraft is diving. Apart from the difference in individual reaction, the strength of this feeling is directly dependent on the speed at which the turn is made and the rapidity of the movement of the head.

*g. Vertigo.*—An interesting type of angular acceleration is that which occurs when an *active movement of the head is made in a* plane at right angles to the plane of passive rotation. In this condition, if a pilot, when in a spin, should move his head up or down, a marked vertigo is induced from which it is extremely

them rely for their success on a combination of visual and auditory aids In addition, an aircraft is in touch by radio with ground stations, which can fix its position with accuracy and provide the pilot with the necessary information when required

## LATERAL INSTABILITY SYNDROME

**1. General.**—This syndrome is of interest as it constitutes an entity in itself and combines several of the psychological and physiological factors associated with the maintenance of equilibrium It has never been a large-scale problem but is worthy of inclusion because of its potential danger and its application to problems of instrument flying It originally arose during the last war and was peculiar in that it was concerned only with experienced pilots flying high-speed sensitive aircraft by night, on instruments

**2. Symptoms.**—The symptoms consisted of a gradually-increasing sensation that the aircraft was revolving about its longitudinal axis whilst in flight It commenced with the impression that one wing was slightly low, and this feeling gradually became more intense until the pilot was convinced that the machine was going to turn over completely A good pilot when experiencing a sensation of this sort, would immediately refer to his instruments for reassurance as to his spatial orientation, and ignore the impressions, but in some cases, the sensation became so overwhelming that they disregarded their instruments and took what they thought was appropriate corrective action

**3. Effects.**—The effects of such an action on aircraft which was actually on an even keel were that aerodynamic stability was upset, resulting in various unexpected aerobatic manœuvres. Thus a set of circumstances was produced from which it was difficult, and sometimes impossible, to recover, and which were fatal in a number of cases In the case of such pilots as survived by compelling themselves to rely on their instruments rather than these powerful somatic sensations, all were extremely exhausted mentally and physically when examined afterwards

**4. Investigation.**—Detailed investigations were carried out on the eyes, ears, nose and throat, and general physical system The aircraft was examined for aerodynamic irregularities, the pilot's flying record was examined, and he was tested on instrument flying in the Link Trainer. His psychiatric record was investigated and an attempt was made to reproduce the condition on other aircraft

**5. Findings.**—The results of these findings were that there were no demonstrable physical defects in the pilots concerned, their flying records were above average, no defects were found in

the aircraft, and the only possible item of interest was that some of the personnel had a doubtful previous psychological history which had not been considered of sufficient gravity to merit attention hitherto

**6. Aetiology.—**

*a. Predisposing Factors.*—There were, however, certain predisposing physical factors which played a part in the onset of the condition :—

i. The windscreen was offset, and while this did not matter when it was clean, it is known that optical accuracy can be impaired when glass is dirty.

ii The vertical pillar about which the rudder bar operates in the aircraft concerned was slightly offset, and not central relative to the pilot.

iii A multiplicity of accessory equipment was so placed as to exercise constant pressure on one side of the pilot when sitting in the cockpit.

iv. The aircraft was very sensitive, and the slightest movement or adjustment in the controls resulted in great variations in the flying position

v Several of the pilots concerned, as stated above, had a dubious psychological background and were liable to react adversely to an unfavourable set of circumstances.

vi Lastly, and most important, all were going through a period of very great operational strain and fatigue, consequent upon the inability to give them adequate leave, owing to the prevailing state of the war

*b Exciting Factors*—The predisposing factors being present as mentioned in the previous paragraph, all that was needed was some trigger to set the sequence of events in motion. It has been mentioned previously how correct visual interpretation is of paramount importance in flying. When an aircraft has been flying in cloud for some time a pilot is fatigued and not at his best, and if at such a time the aircraft comes out of cloud into a space between two cloud layers he may get a false impression of the horizon due to the junction of two cloud banks, at an angle As he has no air to ground visual interpretation to correct this idea, he immediately gets an incorrect impression of the horizontal which may be further distorted by the effects of a dirty windscreen. Before he goes into cloud again to fly by his instruments, a firm impression has been created in his mind that the aircraft is not on an even keel. From then on the other factors play their part in the summation of somatic impressions he receives, producing an overwhelming feeling that the aircraft is not flying level, with results as described

Such conditions would not of course arise in aircraft fitted with an automatic pilot.

7. **Comment.**—Every pilot during his training goes through a period when he finds it difficult to trust his instruments rather than his own senses, on which he has hitherto relied. This impression is corrected as a result of practice, and in due course he comes to rely implicitly on instruments whatever his personal feelings may be. If he makes mistakes during training, the type of aircraft used at that stage is usually so constructed aerodynamically that it does not react swiftly or violently to alterations in the controls, and, furthermore, an instructor is usually present to guide and correct mistakes In a high-performance operational aircraft, however, these factors do not apply, and, furthermore, a person who is suffering from operational strain and fatigue plus a certain degree of apprehension is not at his best, and is less able to deal with such a set of circumstances when they arise. The pilots concerned were, in effect, going once again through a period when they were unable to trust their instruments, although on this occasion they had none of the safety factors, such as were present with them in the training stage, to prevent mishaps The result was that in many cases false sensory impressions gained the upper hand

8. **Treatment.**—With these points in view treatment was conducted along the lines of increasing confidence in the type of aircraft, adequate rest and spacing of operational demands upon the personnel concerned, and removal of those persons who fostered this feeling of lack of confidence, or who dwelt unduly upon symptoms when they occurred. A healthy, realistic approach to the problem was attempted and every effort made to avoid exaggeration or unnecessary attention being focused on the condition

9. **Results.**—As a result of this method of approach to the problem the symptoms slowly cleared up, and finally disappeared altogether in the course of a few months. The syndrome provides an interesting example of the interaction of physiological and psychological factors, and the design and structure of an aircraft combining to produce serious trouble in the operation of what was fundamentally an extremely sound aircraft. There are many factors which contribute towards the safe operation of any aircraft, and none can safely be ignored, because, while relatively unimportant in themselves, they may lead to a train of circumstances which in combined form cannot be so easily controlled The maintenance of a state of equilibrium when an aircraft is airborne is of paramount importance, and when this is lacking any sequence of disasters may follow.

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iii A multiplicity of accessory equipment was so placed as to exercise constant pressure on one side of the pilot when sitting in the cockpit.

iv. The aircraft was very sensitive, and the slightest movement or adjustment in the controls resulted in great variations in the flying position.

v Several of the pilots concerned, as stated above, had a dubious psychological background and were liable to react adversely to an unfavourable set of circumstances.

vi. Lastly, and most important, all were going through a period of very great operational strain and fatigue, consequent upon the inability to give them adequate leave, owing to the prevailing state of the war.

*b. Exciting Factors*—The predisposing factors being present as mentioned in the previous paragraph, all that was needed was some trigger to set the sequence of events in motion. It has been mentioned previously how correct visual interpretation is of paramount importance in flying. When an aircraft has been flying in cloud for some time a pilot is fatigued and not at his best, and if at such a time the aircraft comes out of cloud into a space between two cloud layers he may get a false impression of the horizon due to the junction of two cloud banks, at an angle As he has no air to ground visual interpretation to correct this idea, he immediately gets an incorrect impression of the horizontal which may be further distorted by the effects of a dirty windscreen. Before he goes into cloud again to fly by his instruments, a firm impression has been created in his mind that the aircraft is not on an even keel. From then on the other factors play their part in the summation of somatic impressions he receives, producing an overwhelming feeling that the aircraft is not flying level, with results as described

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7. **Comment.**—Every pilot during his training goes through a period when he finds it difficult to trust his instruments rather than his own senses, on which he has hitherto relied. This impression is corrected as a result of practice, and in due course he comes to rely implicitly on instruments whatever his personal feelings may be. If he makes mistakes during training, the type of aircraft used at that stage is usually so constructed aerodynamically that it does not react swiftly or violently to alterations in the controls, and, furthermore, an instructor is usually present to guide and correct mistakes In a high-performance operational aircraft, however, these factors do not apply, and, furthermore, a person who is suffering from operational strain and fatigue plus a certain degree of apprehension is not at his best, and is less able to deal with such a set of circumstances when they arise The pilots concerned were, in effect, going once again through a period when they were unable to trust their instruments, although on this occasion they had none of the safety factors, such as were present with them in the training stage, to prevent mishaps The result was that in many cases false sensory impressions gained the upper hand.

8. **Treatment.**—With these points in view treatment was conducted along the lines of increasing confidence in the type of aircraft, adequate rest and spacing of operational demands upon the personnel concerned, and removal of those persons who fostered this feeling of lack of confidence, or who dwelt unduly upon symptoms when they occurred. A healthy, realistic approach to the problem was attempted and every effort made to avoid exaggeration or unnecessary attention being focused on the condition

9. **Results.**—As a result of this method of approach to the problem the symptoms slowly cleared up, and finally disappeared altogether in the course of a few months The syndrome provides an interesting example of the interaction of physiological and psychological factors, and the design and structure of an aircraft combining to produce serious trouble in the operation of what was fundamentally an extremely sound aircraft There are many factors which contribute towards the safe operation of any aircraft, and none can safely be ignored, because, while relatively unimportant in themselves, they may lead to a train of circumstances which in combined form cannot be so easily controlled The maintenance of a state of equilibrium when an aircraft is airborne is of paramount importance, and when this is lacking any sequence of disasters may follow.

## CONCLUSIONS

To sum up the conclusions reached with regard to equilibrium, it may be said that equilibrium in the air demands:—

1. Sight, which is an entirely reliable factor, and depends either on terrestrial observations or, more important, correct interpretation of instruments.

2 Muscle and somatic sense, which is variable both in intensity and reliability

3. Sound vestibular and labyrinthine organs, sensations from which are very powerful, but at the same time can be very misleading

4. Instrument training, which in modern aircraft of high performance operating under all types of weather conditions must be of a very high standard.

If all the above-mentioned factors are operating there is no difficulty in equilibration, but should vision be lacking false impressions may well be given by the other three The somatic senses are very important adjuvants but must be regarded only as such, and too much importance should not be attributed to them. Sound basic training on instrument flying technique is essential if a high standard of reliability is to be attained, and this must be implemented by refresher courses at regular intervals in a pilot's career, when any incipient weaknesses can be rectified before they have developed to a dangerous degree.

Such methods are adopted by a majority of airlines to-day and enforced by stringent international regulations affecting the issue of pilots' licences, with the result that a very high standard of safety is achieved.

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## CHAPTER X

# PRESSURIZATION

### GENERAL

THE advantages of altitude in military aviation are obvious. Some assessors of operational flying have gone as far as to say that it is one of the most important factors in aerial welfare, and that those who get up the highest, the soonest, and stay there the longest, have an advantage over their opponents which cannot be matched by other considerations. In civil aviation the advantages, although quite different, are very important from an operational point of view. Some of the more important of these considerations are —

1. More efficient engine performance is obtained at height than at ground level. This is particularly so with jet propulsion engines, and results in greater thrust, speed, and power from the same engine with less fuel consumption.

2. Less air turbulence, with resultant more stable conditions of flight and less stress on the aircraft structure.

3. Less resistance to the motion of the aircraft, allowing higher speeds for the same engine thrust.

4. More stable meteorological conditions with absence of cloud, resulting in more accurate weather forecasts and correct anticipation of flight conditions. At heights of 30,000 ft. and more the winds tend to blow consistently in one direction for long periods at a time at high velocities, and full advantage can be taken of them when flight plans are being made.

5. Absence of icing conditions. Icing is a very serious problem in airline operations and any arrangement which will minimize it is an obvious advantage. At heights of 30,000 ft. and more icing is rare.

It may safely be said that the majority of long-distance flights of the future will be conducted at heights round about 40,000 ft. and therefore all problems which arise in connexion with flying at that height or higher must be fully considered.

The main disadvantages to the human system of flying at great heights fall mainly under the following headings.

*a* Decompression sickness.
*b* Anoxia
*c*. Abdominal distension
These disabilities are discussed fully in subsequent chapters

*Table IX*—EQUIVALENT (ANOXIC) ALTITUDES (IN FT) BREATHING AIR AND OXYGEN

| | | | | | |
|---|---|---|---|---|---|
| Breathing oxygen | 40,000 | 42,000 | 44,000 | 45,000 | 46,000 |
| Breathing air | 14,000 | 18,000 | 22,000 | 25,000 | 28,000 |

(*After Roxburgh*)

At 18,000 ft. the atmospheric pressure is 380 mm Hg, or half an atmosphere, at 33,500 ft the pressure is 190 mm Hg, and at 45,000 ft. it is 110 mm Hg, or one-seventh of an atmosphere Thus even though the aviator breathes 100 per cent oxygen at an altitude of 40,000 ft he will develop anoxia, as shown in *Table IX*. This is due to the other factors concerned in alveolar oxygen partial pressure, mentioned in the chapter on RESPIRATION At that height the partial pressure of alveolar oxygen is only 53 mm Hg, or the equivalent of flying at approximately 14,000 ft without oxygen It is apparent that methods to overcome the disadvantages inherent in high-altitude flying may be achieved by attempting to reproduce in the air, at those altitudes, conditions simulating those at or near ground level, and in practice it has been found that something of this nature is essential in all operations conducted over 30,000 ft, and is of advantage at much lower altitudes

## SYSTEMS IN USE

Broadly speaking, the methods to this end fall into three groups—namely, pressurized suits, pressurized breathing, and pressurized cabins Briefly their merits and demerits are as follows —

**1. Pressurized Suits.**—In this method a garment is used which can be inflated so as to give required conditions of pressure, and in the early stages of experimentation in this subject was the only method employed It possessed, however, many disadvantages which have caused its discontinuance for practical purposes, among these being its extreme bulk and rigidity, making it difficult, if not impossible, for the person wearing it (*Fig* 75), to carry out normal duties in an aircraft There was also difficulty in evaporating sweat and keeping the transparent face-piece clear It was used in some of the early attempts on altitude records but has been superseded by other methods for obvious reasons In future it

may become necessary as an emergency measure in pressurized cabin aircraft flying above 45,000 ft

**2. Pressurized Breathing.**—During the war a partial pressure suit, or pressurized breathing, was used operationally with success.

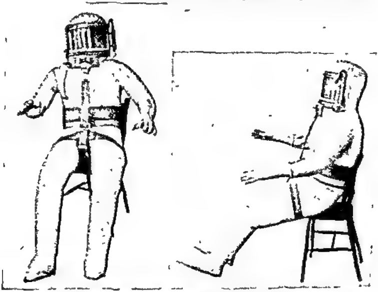

*Fig* 75.—Pressure suits used by the Royal Air Force in high-altitude record attempts (*Royal Air Force photograph* *Crown copyright reserved*)

The problems of oxygen supply at heights greater than approximately 40,000 ft and the presence of German reconnaissance aircraft at heights exceeding this, led to the institution of some methods of supply whereby such heights could be attained with an apparatus not accompanied by the structural and weight problems

*Table X*.—Equivalent (Anoxic) Altitudes (in ft) using Pressurized and Unpressurized Equipment

| | | | | | |
|---|---|---|---|---|---|
| Pressure equipment 100 per cent $O_2$ 8 in water pressure | 38,000<br>48,000 | 40,000 | 42,000 | 44,000 | 46,000 |
| Standard equipment 100 per cent $O_2$ only | 36,000<br>45,000 | 38,000 | 39,500 | 41,500 | 43,000 |

(*After Roxburgh*)

[illegible]

*Fig* 76 —Pressurized breathing equipment

oxygen content of the blood would fall below the normal physiological limit To overcome this, oxygen was introduced through a mask at a positive pressure slightly higher than that of the surrounding atmosphere. The oxygen content of the blood was thereby increased and the physiological ceiling raised (*Table X*) In some forms of pressurized breathing counter-pressure is applied to the outside of the chest to facilitate respiration.

The apparatus consists of a pressure jacket or waistcoat worn by the user which is in circuit with the aircraft's normal oxygen supply system, and constitutes the reservoir from which the mask is supplied

(Figs 76, 77) In designing such an apparatus the following factors have to be considered —

*a.* Comfort for the wearer.

*b* Absence of interference with normal bodily function, and in particular free movement of the arms and legs for control of the aircraft.

*c.* Absence of interference with the venous return from the extremities and head and neck. This need, of course, limits the pressure at which it is possible to breathe. Thus too high a pressure

Fig 77 —Pressurized breathing equipment

on the vagal area of the neck might induce collapse, and the introduction of oxygen with a relatively high pressure differential into the mouth would produce uncomfortable distension of the cheeks In practice the maximum desirable pressure for fulfilling these requirements was found to be 8 in. of water or 15 mm. Hg

*d* Under normal conditions of respiration, inspiration is active and expiration passive, but it will be seen that in pressure breathing this process is reversed and inspiration becomes passive and expiration active. It is important that users of the apparatus have this point made clear to them before use.

The introduction of oxygen up to the maximum of 15 mm of mercury by the apparatus described, results in a raising of the ceiling from 43,000 to 46,000 ft *Table X* indicates clearly the

lvantages to be gained from its use, assuming that 100 per cent ygen is breathed. With the system it should be noted that any ask leaks are outward

Certain precautions are required when the apparatus is used rst, the candidate should be tested in a low-pressure chamber r a minimum period of two hours to see that he does not suffer y ill effects from its use. At the pressure under consideration ry few cases of this sort occur. Secondly, the equipment must e individually fitted to each user, as correct apposition to the face d avoidance of leaks is important Thirdly, aircrew should be ught how to use the apparatus and thus gain familiarity with e technique. Prior to using the equipment it is desirable for ers to breathe 100 per cent oxygen at ground level for 45–50 inutes to avoid decompression sickness The rate of ascent should ot be greater than 3000 ft per minute up to 20,000 ft, gradually ecreasing to 1,000 ft. per minute over 30,000 ft, during cent 100 per cent oxygen should be breathed During descent e equipment should be gradually turned off, until at heights of ,000 ft or less oxygen is being supplied at normal pressure

In practice, experienced users of this equipment found that it stified the claims made for it and that a person can remain ficient for several hours at 42,000 ft and even greater altitudes r shorter periods. Provided a clear understanding of the principles volved is inculcated into subjects using it, and the precautions escribed are taken, it is a satisfactory piece of equipment for the urpose for which it was designed

3. **Pressure Cabins.**—The advent of the pressure cabin has eatly simplified all problems of oxygen supplies (*Fig* 78) although has brought a number of other problems in its train Briefly, ie principle of pressurized cabins is to introduce air by means f a mechanically driven impeller so that a constant pressure is aintained in the cabin of the aircraft irrespective of the external mospheric pressure (*Fig* 79).

PROBLEMS OF PRESSURIZATION.—Among the engineering prob- ms associated with pressure cabins are the following —

*a* *Weight*—This is always of great importance in aviation equirements and the apparatus required considerably reduces the ay load of an aircraft

*b* *Sealing*.—The structural problems involved in pressure cabins re considerable, involving as they do adequate sealing of all aper- ures, the provision of non-return valves for toilets and ventilators, nd specially strengthened doors and windows, all of which mean reater structural strength in the fuselage, with its accompanying eight penalty

*c. Humidity*—At great heights the air is very dry and when compressed and heated the relative humidity is too low for ideal comfort. This may be corrected by moistening incoming air. A relative humidity of 25–50 per cent has in practice been found to be best for the comfort and efficiency of aircrew and passengers.

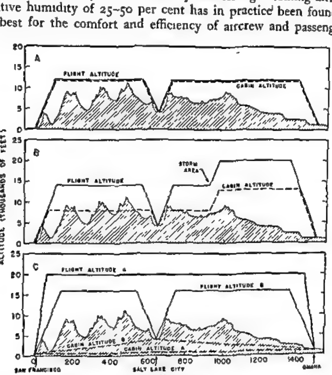


*Fig* 78—Diagram illustrating the advantages to be gained by using pressurized cabins A, Unpressurized cabin B, C Pressurized cabins (*From 'Human Factors in Air Transport Design', by R McFarland By courtesy of the McGraw-Hill Publishing Co*)

The loss of pay-load brought about by the carriage of water probably justifies lower humidity than the ideal, however, particularly if the flight is of short duration

*d. Temperature Control*—An average temperature throughout of 68–70° F. should be aimed at. Care should be taken that incoming air is not more than 100–125° F. If hotter than this it can cause considerable discomfort. Various methods of heating are employed, including the following, which are discussed in detail in Chapter XI

i Hot-air pipes heated by the exhaust system

ii Convection heating, in which warm air is circulated throughout the aircraft by an impeller.

iii Hot-water circulation—a cumbersome and heavy method

iv Panel heating—this method is the most desirable and has many advantages over other types of heating

*e. Noxious Fumes*—This does not present a serious problem as, owing to the raised relative positive pressure, ingress of such gases is prevented It is discussed in detail in Chapter XI

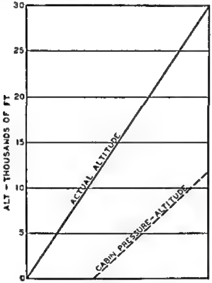


*Fig* 79—Relationship between actual cabin altitude using 5 lb differential pressure

ADVANTAGES OF PRESSURIZATION—The following advantages arise from the use of pressurized cabins —

*a* The utilization of oxygen masks is unnecessary if the cabin is pressurized to heights of less than 10,000 ft. This results in greater comfort and freedom of movement for all occupants Present-day commercial practice is to make the cabin altitude considerably lower than this, namely, 5,000 ft

*b*. Ear and sinus disturbances and pain from gastro-intestinal distension are minimized

*c* Aero-embolism is prevented

*d* The design of the cabin provides good sound insulation, thus diminishing the effects of noise and vibration

*e* Fatigue is diminished

METHOD OF SUPERCHARGING—Pressurizing is accomplished by means of a supercharger which introduces air at a pre-arranged

rate, varying with the atmospheric pressure outside the
The rate of air leaving the cabin is controlled by a pressure co
valve which can be set, so that, within limits, any chosen pre
or rate of pressure change will operate inside the cabin
relation between actual altitude, and cabin pressure altitude
a cabin differential pressure of 5 lb to the sq in, is shown
Fig. 79, and differential rates of climb utilized with pressure cab
is shown in Fig 80, with different rates of climb these figu

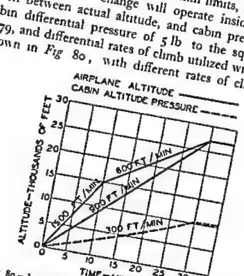


Fig 80 —Variations in rate of climb with partial pressurization

are not applicable, although the basic fundamentals still apply. For operation without discomfort the rate of change of pressure should not be greater than 0 16 lb per sq in/per min, or 300 ft. per min at sea level

Typical differential pressures required for various cabin heights are shown below It will be seen that a greater differential pressure is required at lower levels.

| *Actual Altitude* ft | *Cabin Altitude* ft | *Differential Pressure* lb/sq in. | *Differential Altitude* ft |
|---|---|---|---|
| 50,000 | Ground level | 13 02 | 50,000 |
| 50,000 | 10,000 | 8 43 | 40,000 |
| 50,000 | 20,000 | 5 08 | 30,000 |
| 44,000 | Ground level | 12 46 | 44,000 |
| 44,000 | 18,000 | 5 10 | 26,000 |
| 40,000 | 18,000 | 4 61 | 22,000 |
| 40,000 | 10,000 | 7 38 | 30,000 |
| 30,000 | Ground level | 10 33 | 30,000 |
| 30,000 | 10,000 | 5 74 | 20,000 |
| 20,000 | Ground level | 7 94 | 20,000 |
| 20,000 | 8,000 | 4 14 | 12,000 |

Problems of temperature, humidity, ventilation, and exclusion of noxious gases are dealt with in detail in Chapter XI, but it will be seen that the maintenance of correct respiratory exchange at all altitudes is of fundamental importance in civil and military flying for the maintenance of efficiency, comfort, and life

## SUMMARY

Pressurized suits have too many disadvantages for their practical application to operational flying Pressurized cabins have reached a high degree of efficiency and trouble-free maintenance They increase the operational ceiling, lessen the need for cumbersome and restrictive oxygen equipment, and diminish other disadvantages of high-altitude flying. Pressure breathing apparatus has its place in specialized cases, and where high altitude is required without a pressure cabin

Some of the dangers and operational problems associated with pressurized equipment are discussed in Chapter XVI

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## CHAPTER XI

# TEMPERATURE, VENTILATION, HUMIDITY, AND NOXIOUS FUMES

## TEMPERATURE

THE temperatures in which aircrew have to operate vary through the widest possible range, from extreme desert heat to long periods under sub-zero conditions. The problem of excessive heat is a much easier one to deal with than that of excessive cold and no great obstacles have been encountered in cooling methods in aircraft. It is a relatively simple matter of mechanical procedure to ensure adequate refrigerated ventilation in aircraft operating in hot conditions.

*Table XI*.—APPROXIMATE EFFICIENCY LOSS DUE TO LOW TEMPERATURES

| TEMPERATURE deg. F | EFFICIENCY | |
|---|---|---|
| | Percentage Loss | Total Percentage remaining |
| 50 | 0 | 100 |
| 40 | 10 | 90 |
| 30 | 10 | 80 |
| 20 | 3 | 77 |
| 10 | 7 | 70 |
| 0 | 2 | 68 |
| —10 | 30 | 38 |
| —20 | 5 | 33 |
| —30 | 10 | 23 |
| —40 | 10 | 13 |

(*After Armstrong*.)

A relative altitude-pressure-temperature table is shown in *Table I* (p. 15) and operations under conditions of low temperature require constant attention by designers of aircraft, aircrew, and medical officers to combat the effects of cold by prevention or treatment. The effects of such changes of temperature, if untreated, lead to a marked *loss of efficiency*, *illness*, and, in extreme cases, death. *Table XI* shows the estimated loss of pilot efficiency from

reduced temperatures in open aircraft, and while these factors are to a large extent minimized in closed aircraft the basic essentials are the same. It should be noted that there are three main temperatures at which efficiency drops off rapidly. They are respectively, 30–40° F., –10° F., and –20–40° F.

The absolute moisture content of the air, i.e., the quantity of water vapour contained in the air, augments the cooling effect of the air by increasing the conduction of heat from the skin. The water-vapour content of air decreases rapidly with falling temperatures, so that at –10° C. air may be regarded as practically free from moisture. This is shown in *Fig.* 81. The factors largely

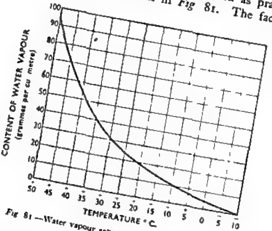


*Fig.* 81.—Water vapour saturation at various temperatures.

responsible for the production, control, and loss of body heat are to a great extent dependent on variations of the basal metabolic rate. The rate of production of heat when the body is in a resting condition, known as the 'basal metabolic rate', is the heat produced in the body as the result of combustion or oxidation of food in those processes which keep the body alive; factors which raise or lower this basal figure are among the controllers of body temperature.

**1. Factors which increase Heat Production.**—

*a. Exercise and Work.*—Moderate exercise, such as walking, may raise heat production to three times the basal rate, and extremely hard work or exercise may increase it ten to fifteen times. Even the small amount of exertion required to maintain the body in a sitting posture increases production 10–20 per cent above the basal rate. Shivering, being the involuntary movement of groups

of muscles in the body, is a form of exercise and may increase metabolism to four or five times the basal rate. It is one of the most effective mechanisms which the body possesses for increasing the production of heat, and maintaining a constant body temperature under conditions of cold environment. Intense mental work, however, only increases metabolism by a very slight amount.

*b Ingestion of Food*.—The production of heat begins to increase within an hour after food is eaten, reaches a maximum of 10–30 per cent above the basal rate at about the third hour, and is maintained at this level for several hours. This increase is due to excess energy needed to digest and assimilate the food into suitable forms for use in the body. Proteins, on account of their specific dynamic action, and fats are the greatest heat producers among ingested foods, and an adequate supply should always be included in the diet.

*c Extrinsic Factors*.—These include the wearing of electrically heated clothing, the application of hot packs and hot bottles to various parts of the body, and the heating of cabins. They are of secondary importance compared with the intrinsic factors mentioned above, but at high altitudes are essential adjuvants to normal sources of bodily heat, in unheated aircraft.

**2. Factors which decrease Body Temperature.**—

*a Evaporation* (excluding sweating).—This occurs via the respiratory tract. Inhaled air is normally relatively dry, but becomes saturated with water vapour at body temperatures while it is in the lungs, and is thus laden with moisture when exhaled. For every gramme of water thus evaporated the body loses about 580 calories of heat.

*b Perspiration*.—There are two forms, the first of which is sensible perspiration or sweating. In this case water is brought to the surface of the skin by the activity of the sweat glands and may, on a hot day, represent 95–98 per cent of the total heat loss of the body. When the body is cold and the sweat glands are inactive it represents an almost negligible figure.

Insensible perspiration represents water lost from the skin by the diffusion of water vapour through the epidermis, is a loss which is entirely independent of the sweat glands, and remains fairly constant under a wide variety of environmental and physiological conditions.

*c Radiation*.—Heat loss by this method is dependent on the difference in temperature between the surface of the body and surrounding objects and is of particular importance in high-altitude flying. It is a loss which can be combated by the use of appropriate clothing.

*d Convection.*—This is brought about by the difference in temperature between the surface of the body and the surrounding air, and varies with the rate of movement of the air over the surface of the body. It becomes of particular importance in operational flying, where the temperature of the internal air of the aircraft can be very quickly reduced by the air entering apertures caused by any fracture in the framework of the fuselage. This factor of heat loss can also be combated by the use of suitable clothing.

*e Conduction.*—This factor is only of importance where the body of a person comes in contact with objects of a very much lower temperature, and is particularly noticeable in the case of rear-gunners, who for long periods hold guns and other metal objects at extremely low temperatures. Adequate insulation between the metal and the person, in addition to artificial heating, is the solution in such cases.

*f Warming of Inhaled Air.*—This is of great importance in aviation as the temperature of inhaled air may be as low as −40° F. and the warming of this air may account for a loss of 10–15 per cent of the total loss of body heat.

*g Excreta.*—An appreciable loss of body heat occurs via excreta.

**3. Temperature Control.**—Control within the body is governed by the temperature-regulating centre in the medulla, and maintains an internal temperature of approximately 98.4° F. through wide ranges of external temperature.

The chief methods of combating heat loss are as follows:—

*a. Cabin Heating.*—The objective in cabin heating is to maintain an evenly distributed temperature in the circulating air in all parts of the aircraft. Excesses of heat or cold are to be avoided, as also are wide temperature variations in different parts of the aircraft, or draughts of hot or cold air playing on one particular part. It will be seen that the three problems of temperature, ventilation, and humidity of the atmosphere in an aircraft cabin are very closely allied, and should, therefore, be considered in relation to one another.

The average cabin temperature throughout an aircraft should be between 68° and 72° F. (dry bulb). Care should be taken to ensure that the incoming air is not more than 100°–125° F. If it is higher than this considerable discomfort will be caused. In military aircraft, however, the cabin temperature can be somewhat lower (50° F.) because the crew will have flying clothing on to prevent the danger of frost-bite in the event of explosive decompression at very great heights caused by enemy action. There are four principal methods of cabin heating used in modern aircraft:—

i By the direct conduction of exhaust gases in pipes through he fuselage. This method is undoubtedly the most economical,

as it uses only existing heat which would otherwise be wasted. It has two principal disadvantages, however. First, the temperature is not uniform throughout the aircraft. Thus it is very hot in the front where the gases have just left the engines and gradually cools off as it passes down the pipes, until at the rear of the aircraft very little heat at all is received Secondly, the slightest leak in the system would result in carbon monoxide entering the cabin, with consequent danger to life

ii. Circulation of hot water in pipes throughout the aircraft. In this system the water is heated electrically or by being passed over exhaust pipes and then circulated as required In practice the necessary pipes and apparatus required have been found to be too heavy for use in aircraft.

iii. Circulation of hot air throughout the aircraft. This is a very good method, in that elaborate apparatus is not required, warming of the air is relatively simple, and the impeller which circulates the heated air can equally well be utilized for circulating refrigerated air in tropical countries

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iv Panel heating, the heating of the panels being achieved electrically or by introducing hot air from one of the systems mentioned above This system has the following important advantages in operation :—

α Heat loss to the cold exterior walls of the aircraft is minimized

β Heat distribution is more uniform.

γ Forced draughts are eliminated or reduced.

δ It lends itself very well to the shape and construction of pressurized fuselages.

ε It is physiologically much better for the occupants of the aircraft as the overall temperature, if evenly distributed in this manner, can be reduced by 5–6° F. A cabin temperature of 65° F. is very comfortable for passengers in such circumstances, whereas in the convection system it may be necessary to have the temperature at about 70° F

*b. Flying Clothing*.—This can be either heated or protective, or both Artificial heat for flying clothing is almost always produced by electrical methods, and it has been found that there are certain parts of the body which it is essential to heat adequately if it is intended to keep the rest of the body warm. In order of importance, these parts are respectively, the small of the back, the abdomen, the soles and backs of the feet, the calves, hands, and arms. Care must be taken that a form of resistance and insulation is used which

prevents overheating at pressure points, or breakdown of the whole system should one part fail; the latest patterns of electrically heated clothing have proved very satisfactory in practice

Protective clothing consists mainly of an adequate supply of loosely-woven materials which provide proper retention of air round the body. To date the most satisfactory underwear has been similar to that worn by the Navy, namely, a very large net-like design for undervests and pants overlaid with a layer of silk On top of this, normal service clothing plus electrically-heated flying suits are worn It is important in this connexion that clothing should not be too tight or constrictive, and that it should be dry Provision for this drying on operational stations is important

## VENTILATION

The problem of ventilation of aircraft is so closely bound up with heating as to be inseparable from it, and it will, therefore, be discussed here

It might be thought that ventilation was a relatively simple problem, being merely a matter of introducing air from outside the aircraft through suitable vents, but this is not so The following desiderata apply when considering the best ventilating system to be used for an aircraft

1 The circulatory system must provide an adequate volume of air per minute for the maximum number of persons liable to be carried in the aircraft

2 The rate of change of air must be sufficient to ensure the correct quantity of fresh air per person

3 Undue draughts or gusts of air must be avoided

4 Rapid changes in temperature must not occur

5 A comfortable degree of humidity must be aimed at

6 If air is re-circulated, unpleasant odours and tobacco smoke must be extracted before re-circulation takes place

7. Care must be taken that the direction of the flow does not result in air from the galley, kitchen, or toilets being directed on to the passengers

8 The temperature must be thermostatically controlled to deal with the varying operating conditions of an aircraft at a particular time.

The above problems can be satisfactorily met by a system which employs an impeller both for circulating existing air and introducing fresh air from outside The air is passed through a diffuser which prevents blasts or draughts impinging on the occupants, and the temperature is thermostatically controlled by passage over

as it uses only existing heat which would otherwise be wasted It has two principal disadvantages, however. First, the temperature is not uniform throughout the aircraft. Thus it is very hot in the front where the gases have just left the engines and gradually cools off as it passes down the pipes, until at the rear of the aircraft very little heat at all is received. Secondly, the slightest leak in the system would result in carbon monoxide entering the cabin, with consequent danger to life.

ii Circulation of hot water in pipes throughout the aircraft. In this system the water is heated electrically or by being passed over exhaust pipes and then circulated as required In practice the necessary pipes and apparatus required have been found to be too heavy for use in aircraft.

iii Circulation of hot air throughout the aircraft. This is a very good method, in that elaborate apparatus is not required, warming of the air is relatively simple, and the impeller which circulates the heated air can equally well be utilized for circulating refrigerated air in tropical countries.

The disadvantage of the system is that the distribution of the heat is not uniform and passengers are liable to have hot air blowing on their feet while the upper extremities are cold, or vice versa.

iv Panel heating, the heating of the panels being achieved electrically or by introducing hot air from one of the systems mentioned above This system has the following important advantages in operation :—

α Heat loss to the cold exterior walls of the aircraft is minimized

β Heat distribution is more uniform.

γ Forced draughts are eliminated or reduced.

δ It lends itself very well to the shape and construction of pressurized fuselages.

ε It is physiologically much better for the occupants of the aircraft as the overall temperature, if evenly distributed in this manner, can be reduced by 5–6° F A cabin temperature of 65° F is very comfortable for passengers *in such circumstances*, whereas in the convection system it may be necessary to have the temperature at about 70° F

*b Flying Clothing*.—This can be either heated or protective, or both Artificial heat for flying clothing is almost always produced by electrical methods, and it has been found that there are *certain parts of the body which it is essential to heat adequately if it is intended to keep the rest of the body warm* In order of importance, these parts are respectively, the small of the back, the abdomen, the soles and backs of the feet, the calves, hands, and arms Care must be taken that a form of resistance and insulation is used which

prevents overheating at pressure points, or breakdown of the whole system should one part fail; the latest patterns of electrically-heated clothing have proved very satisfactory in practice

Protective clothing consists mainly of an adequate supply of loosely-woven materials which provide proper retention of air round the body To date the most satisfactory underwear has been similar to that worn by the Navy, namely, a very large net-like design for undervests and pants overlaid with a layer of silk On top of this, normal service clothing plus electrically-heated flying suits are worn It is important in this connexion that clothing should not be too tight or constrictive, and that it should be dry Provision for this drying on operational stations is important

## VENTILATION

The problem of ventilation of aircraft is so closely bound up with heating as to be inseparable from it, and it will, therefore, be discussed here

It might be thought that ventilation was a relatively simple problem, being merely a matter of introducing air from outside the aircraft through suitable vents, but this is not so The following desiderata apply when considering the best ventilating system to be used for an aircraft

1 The circulatory system must provide an adequate volume of air per minute for the maximum number of persons liable to be carried in the aircraft.

2 The rate of change of air must be sufficient to ensure the correct quantity of fresh air per person

3 Undue draughts or gusts of air must be avoided

4 Rapid changes in temperature must not occur.

5 A comfortable degree of humidity must be aimed at

6 If air is re-circulated, unpleasant odours and tobacco smoke must be extracted before re-circulation takes place

7 Care must be taken that the direction of the flow does not result in air from the galley, kitchen, or toilets being directed on to the passengers

8. The temperature must be thermostatically controlled to deal with the varying operating conditions of an aircraft at a particular time.

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3. Undue draughts or gusts of air must be avoided.
4. Rapid changes in temperature must not occur.
5. A comfortable degree of humidity must be aimed at.
6. If air is re-circulated, unpleasant odours and tobacco smoke must be extracted before re-circulation takes place.
7. Care must be taken that the direction of the flow does not result in air from the galley, kitchen, or toilets being directed on to the passengers.
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hot or cold elements. All air that is re-circulated should pass through an activated charcoal filter for the removal of odours, prior to re-circulation

The volume of circulating air should not be less than 1 lb per person per minute, and if possible should be between 2 and 3 lb. per person per minute The velocity of impelled air should be between 20 and 60 ft per minute, and should not normally exceed 30 ft per minute The ideal temperature for comfort is about 65° F, but this is only possible where the correct degree of humidity is obtained and it should be possible to vary the temperature between 50° F. and 73° F. according to the requirements of a particular flight

## HUMIDITY

The process of pressurization in aircraft cabins results in heating and drying of the air, and steps must therefore be taken to control the humidity of the circulating air Temperature control has already been discussed

Absolute humidity is the actual water vapour content of the atmosphere at any given time Relative humidity is the actual water vapour content of the atmosphere as a percentage of its total possible saturation at a particular temperature Thus relative humidity may be high when the actual humidity is low.

The importance of control of humidity has a twofold aspect. (1) Passengers and aircrew; (2) The aircraft

In the case of the former a relative humidity of less than 20 per cent is uncomfortable for humans There is a noticeable dryness of the mucous membranes, and although it is as yet without proof, it is believed that there is an increased liability to infections of the upper respiratory tract With the effects on the aircraft we are not here concerned except to observe that the adverse effect of a relative high humidity on electrical wiring, delicate instruments, and corrosion of metals is an obvious disadvantage The ideal relative humidity to be arrived at has been found in practice to vary between 25 and 45 per cent

## SUMMARY OF REQUIREMENTS

Briefly summarized, therefore, the atmospheric requirements for the interior of an aircraft should be as follows:—

A temperature of approximately 65°–70° F. thermostatically controlled, a relative humidity of 25–45 per cent, a circulation rate of 30–50 ft per minute, and a guaranteed volume of 2–3 lb. of

air per passenger per minute Not more than 50 per cent of the original air should be re-circulated

Such standards should result in comfortable operating conditions for crew and passengers alike.

## NOXIOUS FUMES

### CARBON MONOXIDE

**1. General.**—The question of noxious fumes in aviation is almost entirely confined to the question of exhaust gases, and has assumed much less importance with the advent of multi-engined aircraft The causative factor is carbon monoxide, which is present in the fumes of aircraft engine exhausts as a result of incomplete combustion of fuel

The concentration of carbon monoxide present in exhaust gases varies considerably, dependent on the type of fuel, the octane rating, the air-fuel mixture, the throttle setting, the altitude (*see Table XII*), and atmospheric conditions, and ranges between 1 and 7 per cent, with an average of 2 8 per cent By the time these gases have reached the fuselage, they have been diluted with atmospheric air, the dilution depending on many factors, including the location of the exhausts relative to the fuselage, the ventilating system, and the condition of airflow over the aircraft There is no physiological significance in concentrations less than 0 005 per cent, but above this figure physiological manifestations can be observed

**2. Methods of Detection.**—Carbon monoxide is a colourless gas with no smell It is non-irritating and therefore its presence may often remain undetected unless suitable precautions are taken Several methods have been adopted for this purpose, the simplest of which is an instrument which registers a colorimetric change when the concentration of carbon monoxide reaches dangerous levels , in practice it has been found to be fairly satisfactory, although it is obvious that the concentration in different parts of an aircraft can vary through a wide range In an alternative system an electrical connexion is created by means of a thermopile when carbon monoxide, present in certain concentrations, is oxidized through the aid of a suitable catalyst. This sensitivity, however, is not adequate to deal with such small concentrations as may be a source of danger

**3. Action of Carbon Monoxide.**—Carbon monoxide has a two hundred-times greater affinity for hæmoglobin than oxygen, and this produces a relative form of anoxia In addition it prevents the liberation to the tissues of such oxygen as is present in the blood, thus aggravating the condition of tissue anoxia

Concern about carbon monoxide poisoning at high altitudes is justified when one realizes that a small loss in the oxygen-carrying capacity of the blood, already impoverished of this gas due to low barometric pressure, can produce dangerous *anoxic symptoms* Different concentrations of carbon monoxide in the blood brought about by different concentrations in inspired air over varying periods are shown in *Fig* 82.

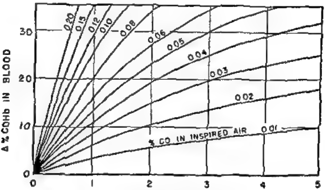


*Fig* 82.—Graph illustrating percentage absorption of carbon monoxide by the blood with varying concentrations in inspired air (*From* '*Human Factors in Air Transport Design*', *by R McFarland* By courtesy of *The McGraw-Hill Publishing Co*)

The elimination of carbon monoxide from the blood proceeds at a constant rate, and is determined by several factors, such as ventilation rate, chemical dissociation of carboxyhæmoglobin, and its elimination through other channels The speed of elimination can be greatly increased by breathing oxygen, and also by stimulation of the respiratory centre by carbon dioxide

**4. Symptoms.**—Symptoms of carbon-monoxide poisoning vary according to several factors —

1 The concentration of carbon monoxide in the air and in the blood

2. The duration of exposure

3. The altitude

the air this point is reached at 14,000 ft, with 0 005 per cent carbon monoxide it is reached at 11,600 ft., and with 0 01 per cent carbon monoxide at 7000 ft. The symptoms vary according to

the concentration of the carbon monoxide, shown below as a percentage (McFarland)

| *Percentage Saturation of the Blood* | *Symptoms* |
|---|---|
| 0–10 | No symptoms |
| 10–20 | Tightness across the forehead, slight headache, dilatation of superficial blood-vessels |
| 20–30 | Headache and throbbing in temples |
| 30–40 | Severe headache, weakness, dizziness, dimness of vision, nausea, vomiting, and collapse |
| 40 and over | Greatly increased pulse-rate, increased respiration-rate, and later coma, loss of consciousness, intermittent convulsions, and death |

This is shown in graph form in *Fig* 83

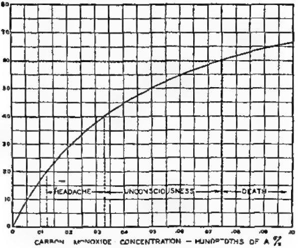


*Fig* 83 — Symptoms of carbon-monoxide poisoning

**5. Desirable Limits for Aircraft.**—In fixing desirable limits for aircraft the effects of carbon monoxide in the air and anoxia due to altitude must be considered together For the purpose of commercial aviation long flights must always be considered and with this in view the maximum permissible amount of carbon monoxide in cabin air should not exceed 0 003 per cent, this results in a blood saturation of slightly less than 4 per cent at sea level Greater concentrations than this will result in visual and other

impairment, a reduced physiological altitude, and quicker onset of anoxia. The combined effects of altitude and varying concentrations of carbon monoxide in the air are shown in *Table XII.*

*Table XII.*—THE COMBINED EFFECTS OF ALTITUDE AND VARIOUS AMOUNTS OF CARBON MONOXIDE IN THE AIR

| Per cent CO in inspired air* | Actual (pressure) altitude in feet | | | | | |
|---|---|---|---|---|---|---|
| | Sea level | 6,000 | 9,000 | 12,000 | 15,000 | 18,000 |
| | Physiological altitude in feet | | | | | |
| 0 002 | 6,800 | 9,000 | 12,000 | 14,500 | 16,800 | 19,200 |
| 0 003 | 8,000 | 10,300 | 13,000 | 15,400 | 17,400 | 19,700 |
| 0 004 | 9,100 | 11,400 | 13,000 | 16,200 | 18,100 | 20,200 |
| 0 005 | 9,800 | 12,300 | 14,700 | 16,800 | 18,700 | |
| 0 010 | 13,100 | 15,600 | 17,500 | 19,100 | | |

* Assuming exposure of sufficient duration for equilibrium with the blood

(*After McFarland*)

## CARBON DIOXIDE

Although not such a serious problem, the question of carbon-dioxide contamination must not be overlooked. A lot of work has not been done on this problem, but White (1948) suggested that the maximum safe concentration at sea-level should be:—

5 volumes per cent for 5 minutes or less.
4 volumes per cent for 15 minutes or less
1 volume per cent for not more than 2 hours.

Carbon dioxide is tolerated better at altitude and, calculated on the figures given above, it will be seen that 7½ volumes per cent is the maximum safe allowance at a cabin pressure altitude of 15,000 ft. The problem in airliners arises because of the considerable carbon-dioxide content of fire-fighting equipment, and it is, therefore, incumbent on all aircraft instructors and flight engineers to ensure that no leakage of this toxic gas occurs from such equipment

## OTHER SOURCES OF NOXIOUS FUMES

Methyl bromide fire extinguishers have been used in aircraft for a long period. This substance *is, however, a most toxic one* and should not be used in the fuselage of pressure cabin aircraft where the chance of it being inhaled by occupants is present.

## TREATMENT

1. *Preventative.*—With modern multi-engined aircraft where the exhaust pipes are well removed from the fuselage, the problem is

not a serious one and colorimetric indicators are not considered necessary Adequate ventilation of aircraft at all times is necessary, with periodic changes of air These items are discussed in detail under the section on ventilation

2. *Curative* —Adequate ventilation of the aircraft and inhalation of pure oxygen in established cases will cause a rapid disappearance of symptoms

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## CHAPTER XII

# NOISE AND VIBRATION

## GENERAL

If a consensus of opinion were taken from all passengers and aircrews as to which single item in flying occasioned them the most inconvenience and annoyance, it is probable that noise and vibration would take first place, and aircraft designers and constructors would do well to place the elimination, as far as possible, of this unpleasant factor high on their list of desirable features in an aircraft. Noise and vibration play an undoubted part in the production of headaches, visual and auditory fatigue, air sickness, and general discomfort observed at the end of a long flight. Elimination of noise and vibration has had striking results in lowering the incidence of fatigue, particularly in military aircraft, where the problem is more predominant than in civilian air transports.

## AETIOLOGY

The total overall noise of an aircraft in flight is made up of a number of individual component noises, of which the more important are the following:—

1. Airscrew tip-speed noise (approximately 122 decibels).
2. Engine explosions and expansion of exhaust gases in piston engines (approximately 118 decibels).
3. Ventilating equipment (approximately 114 decibels).
4. Aerodynamic noises, including slipstream and turbulences occurring around the fuselage (approximately 94 decibels).
5. Overtones and undertones caused by desynchronization of airscrews and other factors (approximately 108 decibels).

By logarithmic addition the total overall noise caused by the factors mentioned above may be in the neighbourhood of 120 decibels. With these factors must be included the problem of pure jet and turbine engine noise in aircraft to-day.

## MEASUREMENT OF NOISE

Measurement of noise is not a straightforward matter because the assessment of a standard on which to base noise levels is an

arbitrary one. Sound intensity is measured in watts per sq cm, while sound pressure is measured in a conventional unit of pressure such as the millibar (1 millibar equals ·00145 lb/sq in) The standard of intensity most widely adopted as a reference above and below which intensity of noise can be measured, corresponds approximately to the minimum audible intensity at a thousand cycles per second, and is equivalent to an energy pressurization of $10^{-16}$ watts per sq cm with a plane progressive sound wave in air at a temperature of 80° F and a barometric

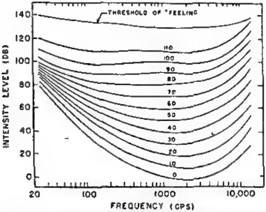


*Fig* 84—The figures on the contours represent the loudness level in phons and show that curves of equal intensity but different frequency do not sound equally loud to the human ear (*After McFarland*)

pressure of 740 mm Hg This corresponds to a sound pressure of 0·207 millibars or 0·0002 dynes per sq. cm This intensity is slightly less than the threshold of audibility for the average ear at a frequency of 1000 cycles per second (*see Fig* 47, *p* 73)

The unit of intensity is called the decibel, a logarithmic unit, and intensity is therefore measured in units (decibels) above or below a certain arbitrary standard Thus, the correct way to identify a noise level in this scale is to say that it is so many decibels above or below $10^{-16}$ watts sq cm at 1000 cycles per second It is important in this case to remember that the decibel is a ratio of intensities rather than an actual physical quantity, the decibel scale merely expressing how much greater one sound intensity is than another In common usage a noise level is referred to as being of so many decibels

Loudness, on the other hand, is a physiological quantity The ear judges sound not only by its intensity but also by its frequency,

so that two sounds of the same intensity and frequency are observed as being of equal loudness. Two sounds of different frequency, however, even though of the same intensity, are observed as being of different loudness Thus the loudness level of a sound is said to be equal to the intensity level of a 1000-cycle note which sounds equally loud

The *unit of loudness is the phon and by definition zero phons* equal zero decibels at 1000 cycles and 10 phons equal 10 decibels if the intensity referred to is 1000 cycles. *Fig.* 84 shows how tones of equal *intensity but different frequencies do not sound equally* loud to the human ear

## EFFECTS OF *NOISE AND VIBRATION* ON THE HUMAN EAR

It is fortunate that the sum total of the effects of noise and vibration on the human ear is not arithmetic but logarithmic. Thus the difference in intensity of two sounds $I_1$ and $I_2$ can be calculated by the formula :—

$$\text{Decibels} = 10 \times \log \frac{I_1}{I_2}$$

By application of this formula, if a sound of 100 decibels intensity ($I_1$) is augmented by another sound, also of 100 decibels intensity ($I_2$), the total intensity of noise produced is not 200 decibels but 103, thus —

$$\begin{aligned} \text{Difference in Decibels} &= 10 \times \log \frac{I_1 + I_2}{I_1} \\ &= 10 \times \log \frac{100 + 100}{100} \\ &= 10 \times \log 2 \\ &= 10 \times \cdot 3 \\ &= 3 \end{aligned}$$

In aviation this is particularly noticeable when standing on an airfield and an aircraft's engines *are started up When the first* engine is started there is a considerable bombardment of the ear with noise. This is not noticeably increased, however, when the the second engine, *the noise of which is of equal intensity, is* also started There is, in fact, very little appreciable difference in noise. It is important to bear this factor in mind when attempts are made to reduce noise levels *in aircraft to reasonable standards*

The effects of prolonged exposure to noise are described in detail in Chapter XIX (AVIATION DEAFNESS), together with methods of personal *protection. This chapter* is concerned with the aircraft itself rather than the occupants.

## NOISE LEVELS

A survey of comparable noise levels met with in everyday life is given below.

| *Conversational Voice* | *Intensity Level Decibels* | *Comparative Noise* |
|---|---|---|
| Whisper | 25–30 | Quiet residence |
| Normal | 50–55 | Quiet car<br>Quiet street |
| Raised voice | 70–75 | Busy traffic<br>Restaurant<br>Trains |
| Difficult to hear | 90–95 | Loud radio<br>Orchestra |
| Shouting | 105–110 | Pneumatic drill<br>Multi-engined aircraft |
| Speech impossible | 125–130 | High-speed aircraft<br>Siren<br>Jet engine |

## DESIRABLE LEVELS OF NOISE AND VIBRATION

It is difficult to establish rigid rules for such requirements, but the following ranges would appear suitable for normal passenger-carrying aircraft at cruising speeds.

| *Location* | *Decibels* |
|---|---|
| Passenger cabin | 75–80 |
| Flight deck | 80–85 |
| Crew quarters | 85–90 |
| Unoccupied parts of fuselage | 95–100 |

It is obviously desirable that all occupied parts of the aircraft shall be sound-proofed to the optimum level, but different levels are here given, because the maximum weight saving is required by economy in the use of sound-proofing materials. Taking these factors into consideration it may be said that an over-all noise level of 80–85 decibels is permissible, but a desirable level would be 50–60 decibels.

With regard to vibration a maximum vector amplitude of 0·002 in. is desirable for crew and passengers, for frequencies over 20 cycles per second.

## METHODS OF REDUCING NOISE

Methods of protecting passengers from the effects of the noise produced by an aircraft in flight may either be primary, which aim at reducing the intensity of noise itself, or secondary, which aim at insulating passengers from the source of the noise. Thirdly,

a combination of these methods may be used. Noises from an airscrew are produced from two main sources, namely, the rotation of the blades and vortex noise. The former has a frequency equal to the number of rotations per second times the number of blades; the latter is caused by the air flow around the tips and is directly proportional to the tip-speed.

Airscrew noise has peculiar directional characteristics which are particularly evident if the airscrew tip passes close to the fuselage, when noise and vibrations of considerable intensity are set up in a relatively localized area, lateral to the plane of rotation. Bearing these factors in mind, therefore, the following steps should be taken in order to reduce over-all noise as far as possible

1 Do not allow the airscrew tip-speed to exceed 800 ft./sec. at cruising speed, if possible it should be considerably less than this, 650 ft./sec is desirable.

2 Ensure that the clearance between airscrew tip and fuselage is at least 12 in., if possible, more

3 Do not allow any part of the passenger compartment to be in the plane of the airscrews.

4. Endeavour to avoid the location of any permanently occupied parts of the aircraft in an area 4 ft. fore and aft of the lateral plane of the airscrews

5 Make every effort to eliminate vibration within the noise cone referred to above, by the provision of rigid structure bracing and adequate sound insulation

6 Exhaust noises should be reduced by the provision of appropriate baffles as far as compatible with efficiency, and also by directing the exhaust pipes away from the fuselage

7. Reduce the speed of the air passing through all ventilating ducts as much as possible

8 Careful elimination of all sources of vibration in the fuselage. It is surprising what a considerable noise level can be reached by summation of a number of noises of this sort, such as rattling window panes or accessory fitments such as lighting and heating panels, all of which can be very trying to passengers

9 An important feature is the provision of suitable insulating material in the walls of the fuselage. Experiment has shown one of the best of these to be some form of kapok or similar fibrous material, but many different systems have been adopted utilizing alternating layers of varying sound-proofing substances. Glass wool is used with success by some aircraft manufacturers.

10 Care must be taken not to incorporate in the facing of the cabin any material, or structural shape, which could act as a resonator

## HIGH-FREQUENCY NOISE

Recent investigations into the physiological effects of frequencies ranging from 10 cycles per second through the sonic to the ultrasonic range, i e, 20,000 cycles per second, reveal that little is known of the effects of ultrasonic vibrations though some work has been done with highly localized sources of vibration on animals

In humans the matter has been studied from the point of view of the low-frequency vibrations as experienced in piloted missiles and the high-frequency effects in certain high-speed jet aircraft

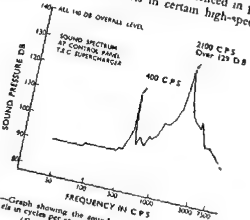


Fig 85 —Graph showing the sound pressure in decibels plotted against frequency levels in cycles per second
(Figs 85–87 by courtesy of the 'Journal of Aviation Medicine')

Under certain conditions pilots have reported peculiar sensations, including dizziness, fatigue, and disorientation, and there has been a noticeably high accident rate Under such circumstances at a frequency of 35,000 cycles per second, an intensity of 125–130 decibels is experienced Further comments on the effects of such frequencies would be out of place until an experimental chamber is in operation which can produce noise up to an intensity of 120 decibels or more at a frequency of 10,000–20,000 cycles per second, as well as an apparatus which would produce air-conducted vibrations at frequencies up to 50,000 cycles per second

Some writers consider that the ill effects experienced may be due to the very large noise volumes at low frequencies, but all are agreed that the insulating effect on pressure cabins will assist in eliminating trouble from this source As an interim measure it is of importance that some method should be devised for the measurement of vibration in different types of aircraft in use

Recent work in America (E S. Mendelson and others), where hearing acuity was measured before, during, and after subjection to jet-engine noise in an enclosed space, indicates that at certain frequencies such noise can reach a very high decibel level, as

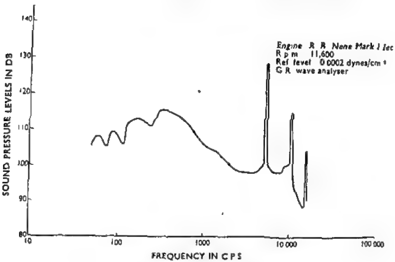


*Fig* 86 —Sound spectrums at control panel during experiment

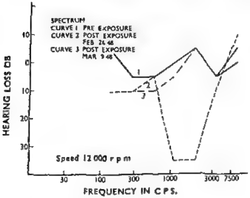


*Fig* 87 —Graph showing hearing loss after exposure to high-frequency engine noise

shown in *Figs* 85 and 86. Exposures in the experiment referred to extended over a period of twenty-six days, and individual exposures varied from one to two hours

The resultant effects on people exposed to such noise, shown in *Fig* 87, demonstrates that there was a considerable degree

of hearing loss as indicated by audiometer readings, and that the matter is one requiring further investigation if trouble in the future is to be avoided Of the various ear protectors tested, cotton-wool was found overall to be the most easily applied, comfortable, and efficient, and resulted in an effective reduction in noise intensity of 25 to 35 decibels

Other findings in the main were negative, although some persons lost weight and almost all felt more tired, nervous, or irritable at the end of the trials In certain cases, apprehension, inability to concentrate, nausea, and faintness were recorded

## CONCLUSIONS

The prevention of noise and vibration in aircraft is properly an engineering problem and it must be left to designers to devise the most satisfactory methods of reducing over-all noise levels. It is for the medical profession, however, to advise as to what noise levels are desirable, undesirable, or positively harmful, and close co-operation between the medical, engineering, and design departments of any airline is necessary if satisfactory results are to be achieved, the effective hearing of aircrew preserved, and the comfort of passengers assured Personal protection of the ears against noise is discussed in Chapter XIX (Aviation Deafness)

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# PART III. MEDICAL CONSIDERATIONS

## CHAPTER XII

# ANOXIA

### DEFINITIONS

ANOXIA may be defined as a deficiency of oxygen in the tissues Four distinct types are recognized —

1 **Anoxic Anoxia.**—This is due to a low oxygen pressure in arterial blood, arising from a low alveolar oxygen tension as encountered at high altitudes Other causes include abnormalities of the pulmonary epithelium, as in pneumonia and other respiratory diseases

2. **Anæmic Anoxia.**—By this is meant a low oxygen-carrying capacity of the blood, as occurs in certain blood diseases or carbon-monoxide poisoning

3. **Histotoxic Anoxia.**—This occurs when there is a poisoning of the cellular oxidative enzymes, as can occur with certain tissue poisons, such as cyanides

4. **Stagnant Anoxia.**—This is caused by circulatory deficiency, due either to congestive cardiac failure or, in acute cases of 'black-out', to excessive 'g'

### GENERAL CONSIDERATIONS

The decrease of alveolar oxygen tension is not proportional to the decrease in the partial pressure of oxygen in inspired air, on

*Table XIII*—THE RELATION BETWEEN ALTITUDE, BAROMETRIC PRESSURE, PARTIAL PRESSURE OF OXYGEN IN THE ATMOSPHERE, AND IN THE ALVEOLAR AIR

| ALTITUDE ABOVE SEA LEVEL | BAROMETRIC PRESSURE | ATMOSPHERIC $pO_2$ | ALVEOLAR AIR $pO_2$ |
|---|---|---|---|
| ft | mm Hg | mm Hg | mm Hg |
| 0 | 760 | 159 | 103 |
| 6,000 | 602 | 126 | 78 |
| 10,000 | 506 | 106 | 64 |
| 14,000 | 444 | 93 | 53 |
| 18,000 | 380 | 80 | 45 |
| 22 000 | 328 | 71 | 36 |
| 28,000 | 253 | 53 | 20 |
| 30,000 | 230 | 47 | |

account of the constant partial pressure of water vapour and carbon dioxide (*Table XIII*) These percentages become relatively greater with increasing altitude. The partial pressure of these two gases remains constant, since they are products of bodily

*Table XIV*.—THE COMPOSITION AND PARTIAL PRESSURES OF ALVEOLAR AIR AT SEA LEVEL AND VARIOUS ALTITUDES

| ALVEOLAR GASES | MILLIMETRES OF MERCURY BREATHING AIR AT SEA LEVEL | MILLIMETRES OF MERCURY BREATHING PURE OXYGEN AT | | |
|---|---|---|---|---|
| | | 30,000 ft. | 34,000 ft | 40,000 ft |
| Oxygen | 100 | 138 | 100 | 57 |
| Carbon dioxide | 40 | 40 | 40 | 37 |
| Nitrogen | 573 | 0 | 0 | 0 |
| Water vapour | 47 | 47 | 47 | 47 |
| Total pressure | 760 | 225 | 187 | 142 |

activity, so that, as atmospheric pressure diminishes with altitude, they constitute an increasing percentage of alveolar air, which results in a decreased percentage of oxygen (*Table XIV*) Thus,

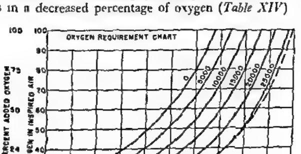


Fig 88.—Alveolar oxygen tension and arterial oxygen saturation variations with altitude

when the partial pressure of inspired oxygen is reduced by one-third, the alveolar oxygen partial pressure is reduced by half, and when the partial pressure of inspired oxygen is reduced by one-seventh, the alveolar oxygen pressure is reduced by one-twenty-third

When atmospheric pressure is reduced to 87 mm. Hg (at a height of 50,000 ft) the alveolar oxygen partial pressure is almost zero. For practical purposes, breathing pure oxygen to counteract the effects of altitude is not effective above heights of 37,000 ft. The reason for this is that breathing pure oxygen does not increase the altitude at which the alveolar oxygen tension in the lungs reaches zero, this condition obtaining at the same altitude in both cases.

their normal supply *Fig.* 88 demonstrates these facts

## COMPENSATORY MECHANISMS

This reduction in oxygen partial pressure results, however, in the following compensatory mechanisms coming into play. First, there is an increased ventilation-rate due to stimulation of the respiratory centre This increased ventilation, however, results in a raised excretion of carbon dioxide and the respiratory centre is subsequently depressed Secondly, the pulse and blood-pressure show a transient rise followed by a depression Thirdly, the phenomenon known as 'Bohr effect' occurs In this condition, when the carbon dioxide content of the blood falls below normal as a result of increased lung ventilation, the blood shows an increased affinity for oxygen and consequently becomes more highly saturated in its passage through the lungs At the same time, however, its retentive power for oxygen is increased and oxygen is not given off so readily to the tissues. The result is a tissue anoxia

## FACTORS INFLUENCING ANOXIA

The effects of anoxia on the human system are dependent on several variable factors, of which the main are as follows —

**1. The Altitude reached.**—On this depends the partial pressure of the alveolar oxygen tension and hence the effective oxygenation of the tissues (*Table XV*).

**2. Rate of Ascent.**—Rates of ascent in modern aircraft have undergone profound changes in recent years and this factor is assuming ever-increasing importance in flying In a very slow rate of ascent acclimatization can take place, but in rapid ascents, as experienced in aviation, failure to use oxygen will result in sudden and extreme changes in pulse and blood-pressure (as demonstrated in the pressure chamber), marked cramp of the lower extremities, fainting, and collapse Varying degrees of error by fighter pilots

in the early stages of the war, when the importance of adequate oxygen was not realized, were directly attributable to failure to use oxygen from the ground up when climbing at high speeds, and in many cases led to accidents and fatalities

*Table XV*—Oxygen Requirements at Altitude

| Altitude | Oxygen Partial Pressure | Blood Saturation | Oxygen required in Inspirate for Normality |
|---|---|---|---|
| ft | mm/Hg | per cent | per cent |
| 5,000–10,000 | 126 5–104 5 | 95–90 | 28 |
| 10,000–15,000 | 85 8 | 90–78 | 35 |
| 15,000–18,000 | 77 5 | 80–68 | 42 |
| 18,000–22,000 | 64 0 | 70–55 | 50 |
| 22,000–27,000 | 51 0 | less than 65 | 70 |
| 27,000–30,000 | 45 0 | | 80 |
| 30,000–37,000 | 32 0 | | 90–100 |
| 37,000–44,000 | 24 0 | | |
| Over 44,000 | | | |

(*After Lovelace*)

**3. Duration of Exposure.**—The effects of anoxia are accumulative, and the longer the exposure the greater the deterioration;

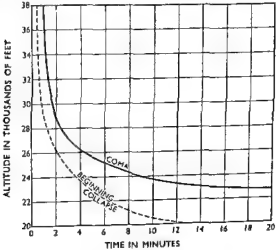


*Fig* 89—Graph showing the effects of deprivation of oxygen at various altitudes

thus, exposure to extreme anoxia for a few moments or a moderate anoxia for a few hours requires similar time for recovery to be

effected The results of exposure without oxygen at varying altitudes are demonstrated in *Fig.* 89 and *Tables XVI* and *XVII*.

*Table XVI*—EFFECTS ON MAN, IF NOT GIVEN ADDITIONAL OXYGEN

| ALTITUDE IN FT | TIME BEFORE BECOMING UNCONSCIOUS | TIME TAKEN BEFORE DEATH OCCURS |
|---|---|---|
| | minutes | minutes |
| 20,000 | 5 (if walking about) | — |
| 25,000 | 7 (if sitting) | 20 to 60 |
| 30,000 | 2½ „ | 15 to 20 |
| 35 000 | 1 „ | 10 to 15 |
| 40,000 | ½ „ | 5 to 10 |

(*By kind permission of Air Marshal Sir H E Whittingham*)

*Table XVII*—RELATIONSHIP BETWEEN RATE OF ASCENT TO, OR THE DURATION OF EXPOSURE AT, VARIOUS ALTITUDES, 100 PER CENT UNCONSCIOUSNESS

| RATE OF ASCENT | DURATION OF EXPOSURE | LOSS OF EFFICIENCY | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0% | 20% | 40% | 60% | 80% | 100% |
| | | | | ALTITUDE | | | |
| ft min | hours | | | | | | |
| 5,000 | | 15,000 | 18,000 | 21,000 | 24,000 | 27,000 | 30,000 |
| 1,000 | | 12,000 | 15,000 | 18,000 | 20,000 | 23,000 | 25,000 |
| 100 | | 9,000 | 12,000 | 15,000 | 18,000 | 20,000 | 22,000 |
| | 1 | 9 000 | 12,000 | 14,000 | 16,000 | 18,000 | 20,000 |
| | 6 | 9,000 | 12,000 | 14,000 | 15,000 | 16,000 | 18,000 |
| | 18 | 9,000 | 11,000 | 13,000 | 14,000 | 15,000 | 16,000 |

(*After McFarland*)

**4. Individual Tolerance.**—There is a profound variation in individual tolerance of physically fit persons to anoxia, the precise reasons for which are not known Age does not appear to play an important part and studies of many cases show no significant features which could be recorded as useful data in this respect

**5. Physical Fitness.**—The athletic, average-weight, physically fit person has a markedly higher altitude tolerance than the over-weight or otherwise inferior individual, and a remarkable increase in altitude tolerance can be observed as a result of the institution of regular physical training exercises and an attempt to raise the general standard of physical fitness in a selected series of cases

**6. Physical Activity.**—The degree of anoxia is directly proportional to the amount of exercise indulged in This needs no further comment.

**7. Psychological.**—Subjects with a dubious psychological background, or those who manifest neurotic symptoms, show poor altitude tolerance In such an investigation it is important to exclude other possible factors, and to discount results other than those cases from which all organic causes can be excluded The type of person is well known in medical practice, frequently complaining of fatigue and exhaustion. Experimentally in the pressure chamber, and in actual practice when flying on operations, their altitude tolerance is markedly low. In many cases examined in which there is some evidence of neurotic predisposition, more oxygen is used per flight, particularly when hazards are encountered, than is the case with more phlegmatic and normal persons This could, of course, be partly accounted for by the increased respiration-rate due to nervous tension, but in addition to this, other manifestations of increased susceptibility to oxygen lack clearly show in such cases

**8. Organic Diseases.**—Any disease which adversely affects the supply of oxygen to the tissues, does of course adversely affect a person's tolerance to altitude, and in this respect diseases of the respiratory, cardiovascular, and hæmopoietic systems are particularly important These problems are discussed in greater detail in Chapter XXVI

**9. Smoking.**—Heavy inhalation of tobacco smoke, on account of the carbon monoxide content, will increase the liability to anoxia by reason of the formation of carboxyhæmoglobin, and a person's altitude ceiling may be considerably reduced in this way

## SYMPTOMS OF ANOXIA

The earliest manifest symptoms of oxygen lack usually commence at about 7000 ft, and a person will become unconscious without oxygen at 35,000 ft in one minute.

**1. The Brain.**—This is the first organ attacked There is a deterioration in judgement, lack of discrimination and perception, and occasionally euphoria There is a free and easy attitude towards problems, hilariousness, carelessness, and lack of skill in the performance of simple tasks, and in general a lack of fineness of control, together with a spurious sense of well-being, not unlike the early stages of alcoholic intoxication

In aerial welfare there is no doubt that a number of pilots on both sides were killed because at height the oxygen supply was

inadequate or became disconnected, whereupon the pilot's sense of responsibility and judgement became diminished, giving an immediate advantage to his opponent. On more than one occasion a pilot came down and reported that he had seen a hostile

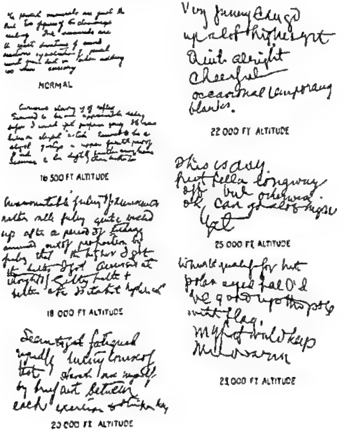


*Fig.* 90.—Alterations in handwriting resulting from anoxia. (From *Keeping Fit for Flying*, by courtesy of *Pan-American Airways System*.)

aircraft in a good position for him to attack it, but that he had not done so; when asked for a reason he was quite unable to give an explanation. Strict attention to the use of oxygen quickly eliminated this state of affairs. A dangerous feature of the situation is that, although obvious to all observers, the subject himself is often

quite unaware that anything is wrong His behaviour appears quite normal to him, though abnormal to others As the condition progresses all mental processes are slowed down, the inaccuracies become more evident (*Fig.* 90), and, without warning, the person may become unconscious.

This is one of the most dangerous features of anoxia, and experiments in the pressure chamber show that a subject can become unconscious when the oxygen supply is cut off and be restored to consciousness again by turning on the oxygen, whereupon he resumes his previous occupation, quite unaware that anything abnormal has occurred In many cases, observed on operations, an oxygen tube became punctured through enemy action, or became accidentally severed, and without warning the person became unconscious

**2. The Eye.**—

*a Visual Acuity*—This is reduced and figures and letters become jumbled and indistinct. The earliest and most classical symptom, however, is a gradual apparent dimming of all lights

*Table XVIII*—Decrease in Night Visual Acuity with Varying Degrees of Anoxia

| Altitude | Average Decrease in Range of Night Vision if Oxygen is not used Starlight Conditions |
|---|---|
| ft (thousands) | per cent |
| 4 | 5 |
| 6 | 10 |
| 8 | 15 |
| 10 | 20 |
| 12 | 25 |
| 14 | 35 |
| 16 | 40 |

At night time this is evidenced by the lighting of the instruments appearing to be dimmed as with a rheostat, whilst by day the pale blue of a clear sky changes to a dark blue, later indigo, and finally black Many pilots have avoided further trouble by noting these early symptoms.

*b Night Vision*—There is a grave reduction in night visual acuity, the rods being peculiarly sensitive to the slightest degree of anoxia, and these symptoms of anoxia precede all others at the lower altitudes, the diminution has been measured practically on the rotating hexagon. The relative reduction in the range of night vision, under starlight conditions, caused by varying degrees of anoxia is shown in *Table XVIII*.

*c Dark Adaptation.*—This process is considerably slowed in anoxia (*Fig* 91) and it is thought that the cause of all the retinal changes is the same, namely, an alteration in the conductivity of the synapses in the retina and in the optic tracts, rather than a photochemical change

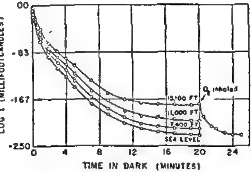


*Fig* 91 —Reduction in dark adaptation due to anoxia (*From 'Human Factors in Air Transport Design'*)

*d Fixation, Convergence, and Deviation.*—There is a change in deviation of the extra-ocular muscles, and a latent deviation will increase until it becomes manifest Vertical deviations will result in diminished depth perception, itself a combination of fusion and stereopsis, a very dangerous condition when landing The cause of this is also thought to be a diminished sensitivity of the synapses, which transmit the nervous impulses preserving the tonus of the extra-ocular muscles

*e Compensatory Mechanisms in the Eye*—Transient compensatory mechanisms are activated in the eye subject to anoxia. There is a temporary vasodilation of the retinal arteries, which is not adequate, however, for the task in hand, and in the case of a latent divergence of the extra-ocular muscles, compensation slowly takes place It is too slow, however, to be of any use to the aviator under the circumstances met with in flying

**3. The Ear.**—Acuity of hearing is diminished, so that slight changes in engine noise, appreciable to other members of the crew, are not heard by a person suffering from anoxia At a later stage intercommunication becomes difficult.

**4. Frost-bite.**—Anoxia increases the liability to frost-bite, and the first place in which this is usually noticed is the extremities, particularly the hands and feet When this is observed a deficient oxygen supply is frequently found to be the cause of the trouble.

5. **Air Sickness.**—The presence of air sickness in one not commonly subject to this complaint is a frequent forerunner of oxygen lack, and can often be remedied by increasing the supply

6. **Respiration.**—Dyspnœa is present to a varying extent according to the degree of oxygen lack present; respiration of the Cheyne-Stokes type is encountered *in advanced stages.*

7. **Cardiovascular System.**—There is a raised pulse-rate, which at times is noticeable to the extent of palpitations. A feeling of dizziness and fainting is a final warning symptom before *unconsciousness* supervenes, but it is of extremely short duration, does not always occur, and is frequently not recognized.

8. **Neuromuscular System.**—There is weakness and aching *in the legs and arms*, *co-ordination* is impaired, and at a later stage tremors and twitchings occur. Following on unconsciousness, which can be quickly remedied by restoring the supply of oxygen, a state of shock is often found. The patient is pale and sweating, with a thin thready pulse and lowered blood-pressure and there is dilatation of the capillaries Survival rates of the average man after complete severance of the oxygen supply at varying heights are shown in *Fig* 89 (p. 180)

## CHRONIC OXYGEN LACK

The effect of a slight reduction in oxygen supply over a long period is difficult to assess, but is nevertheless a well-established fact In such cases there is increased liability to fatigue, and at times nausea and aggravated sensitivity to air sickness, as well as diminished night visual acuity. Reaction times are slowed, and *there is diminished skill in the* execution of relatively simple tasks

The condition most frequently occurs in those flights conducted at intermediate heights, i e, between 7000 and 15,000 ft. In many of these cases it is not felt that oxygen is required, either because the height is not sufficiently great, or because it is considered that not sufficient time will be spent at that height to warrant its use. The symptoms being rather vague and indefinite, a person is *unaware of their onset* The predominant symptom noticeable both to the persons concerned and observers is the greatly increased fatigue, both during and after flight. It is only comparatively recently that it has been appreciated that fatigue can be noticeably diminished if oxygen is used at heights greater than 7000 ft. Under existing circumstances this is not always practicable, but increased attention to the use of oxygen for these heights wherever possible has resulted in a diminished incidence of complaints.

## INDIVIDUAL VARIATIONS TO ANOXIA

There are considerable individual variations in reaction to lack of oxygen, which differences appear to be associated with the differences in sensitivity of individual respiratory centres to oxygen lack The respiratory centre and carotid sinus are controlled mainly by the carbon-dioxide content of the blood and to a lesser degree by the oxygen tension, and these factors would appear to explain the differences in symptoms experienced by different subjects Some become rapidly unconscious without any prior respiratory distress. Others show considerable hyperventilation, followed by violent involuntary movements, at times proceeding to convulsions, before they become unconscious The lowering of the carbon-dioxide content of the blood by hyperventilation appears to be responsible for the symptoms shown by the latter class Furthermore, when oxygen is supplied to a subject about to become unconscious, he may proceed to become unconscious before recovery, and excessive oxygen given to an unconscious subject may produce convulsions before return to normality It is possible that these reactions are due to a sudden change in the acidity of the blood which occurs with the rapid conversion of reduced hæmoglobin to oxyhæmoglobin

## MEASUREMENT OF ANOXIA

The degree of anoxia present is a difficult matter to assess with accuracy, and Goldie devised an anoxia meter by means of which the amount of oxygen in the blood at any given moment could be estimated without resort to withdrawing blood from a vessel The apparatus used measured the oxygen content of the blood by means of two photo-electric cells attached firmly to the lobe of the ear in such a manner as to obtain uniform thickness of tissue. By such means accurate readings can be taken over any required length of time

## TREATMENT OF ANOXIA

This is simple and consists of the following essentials —

**1. Education.**—All aircrew should be instructed in the importance of oxygen, the use of oxygen equipment in aircraft, and the effects of oxygen lack, coupled with practical demonstrations in a decompression chamber

**2. Pre-selection.**—All aircrew should be tested in a decompression chamber up to 40,000 ft and demonstrations given on the effects of anoxia Unsuitable personnel should be eliminated at the training stage

**3. Supply Systems.**—Various supply systems are in use, the object of which is to supply oxygen individually to aircrew and

**5. Air Sickness.**—The presence of air sickness in one not commonly subject to this complaint is a frequent forerunner of oxygen lack, and can often be remedied by increasing the supply.

**6. Respiration.**—Dyspnœa is present to a varying extent according to the degree of oxygen lack present; respiration of the Cheyne-Stokes type is encountered in advanced stages

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This is simple and consists of the following essentials:—

1. **Education.**—All aircrew should be instructed in the importance of oxygen, the use of oxygen equipment in aircraft, and the effects of oxygen lack, coupled with practical demonstrations in a decompression chamber.

2. **Pre-selection.**—All aircrew should be tested in a decompression chamber up to 40,000 ft. and demonstrations given on the effects of anoxia. Unsuitable personnel should be eliminated at the training stage.

3. **Supply Systems.**—Various supply systems are in use, the object of which is to supply oxygen individually to aircrew and

passengers as and when required, with the object of maintaining the alveolar oxygen tension at normality (*Table XV*, and *Fig.* 32, p. 35) The apparatus is described in detail in Chapter II, but briefly consists of a reservoir where oxygen is stored under pressure, whence it is delivered by fixed pipes to various outlet points in different stations throughout the aircraft as required for aircrew and passengers Individual oxygen masks with flexible tubes are provided for all occupants of the aircraft and are connected to the delivery points by bayonet couplings In pressurized aircraft, due to the maintenance within the cabin of normal atmospheric conditions, oxygen apparatus is not required. This equipment is discussed in detail in Chapter II

4. **Treatment of Anoxic Collapse.**—The application of oxygen restores cases suffering from severe oxygen lack, and recovery is usually swift and complete. The addition of 5 per cent carbon dioxide is desirable for the following reasons · First, it increaess the respiratory excursion due to stimulation of the respiratory centre in the medulla Secondly, there is a peripheral vasoconstriction and cerebral vasodilation, resulting in an increased supply of oxygen to the brain Thirdly, there is a shift in the oxygen hæmoglobin dissociation curve, resulting in an increased supply of oxygen to the tissues Fourthly, a minimum cerebral carbon dioxide tension is essential for normal cortical function.

It should be noted that in a few cases of severe anoxia the subject may, to all appearances, seem dead The extremities and lips are livid, respirations are absent, and there is no apparent heartbeat. Careful examination, however, reveals the presence of very occasional diminished cardiac contractions Application of oxygen will usually result in complete recovery Extreme cases of this sort will be considerably shocked, and will require the usual anti-shock therapy, including radiant heat and cardiovascular and respiratory stimulants

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## CHAPTER XIV

# EXPLOSIVE DECOMPRESSION

## GENERAL CONSIDERATIONS

By explosive decompression is meant a sudden lowering of atmospheric pressure as may be caused when the pressurization equipment of an aircraft fails, or the pressure drops due to some structural failure in the fuselage

At sea-level atmospheric pressure is 760 mm Hg, or 16 lb. to the sq in At 20,000 ft it is 349 mm. Hg, or 7 lb to the sq in, while at 40,000 ft it is 141 mm. Hg, or 3 lb to the sq. in Thus it will be seen that at 20,000 ft. the atmospheric pressure is approximately halved, and at 40,000 ft it is approximately one-fifth of the pressure at sea-level

## GENERAL EFFECTS OF LOWERED ATMOSPHERIC PRESSURE

The changes occurring in the human system as a result of lowered atmospheric pressure are physical and physiological The physical changes are those resulting from the behaviour of gases at different atmospheric pressures and affect chiefly the ears, the intestines, and the joints They are of relatively minor importance in the problem at present under discussion, but will be briefly referred to later The physiological problem resulting from lowered atmospheric pressure is that of anoxia. In this connexion a very important fact to be taken into account is that the percentage of oxygen in the lungs does not decrease proportionately with other gases during ascent Thus when the atmospheric pressure is *reduced by half, oxygen in the lungs is reduced to one-third*; when atmospheric pressure is reduced to one-seventh, oxygen in the lungs is reduced to one-twenty-third, and at 50,313 ft. the oxygen partial pressure in the lungs is zero Hence will be seen the importance of maintaining, by artificial means, an adequate oxygen supply for physical requirements at all heights In practice the necessary oxygen partial pressure in the lungs should be not less than 100 mm Hg

## METHODS OF MAINTAINING NORMAL ATMOSPHERIC CONDITIONS IN FLIGHT

This is usually attained by one of two methods, namely, oxygen apparatus for individual use, or pressurized cabins, and it is with the latter that explosive decompression is concerned. The aim in pressurized cabins is to maintain at all actual altitudes cabin conditions such that the occupants remain in safety and comfort without the need for special apparatus such as oxygen masks. These results are obtained by the use of an impeller which maintains a pressure differential of between 5½ and 7 lb to the sq in. between the cabin and the outside air at operational heights of approximately 30,000 ft, this results in a cabin altitude of round about 8000 ft. With greater operating heights bigger pressure differentials will be required. Pressurization of cabins is described in detail in Chapter X.

## SUDDEN (EXPLOSIVE) DECOMPRESSION

When an accident occurs, such as failure of the pressurizing equipment, a leak allowing rapid exhaustion of the cabin atmosphere, or the structural failure of a window or port (explosive decompression), the effects will depend on several circumstances, which will vary in severity according to the following conditions —

1. The degree of change of atmospheric pressure experienced, i e, the difference between cabin altitude and actual altitude at the time of the occurrence
2. The duration of exposure to the lowered atmospheric pressure
3. The physical condition of the person subjected to the change.
4. The speed with which the actual altitude can be approximated to the cabin altitude after the incident occurs
5. Whether adequate oxygen supplies are immediately available
6. The rate of change of pressure

## EFFECTS OF EXPLOSIVE DECOMPRESSION ON MAN

The effects on man fall under four main headings —

**1. Aero-embolism.**—This condition is rare at heights below 30,000 ft, but if the accident should occur at heights greater than this the symptoms will usually disappear as soon as height is lost. It is commonly known as the 'bends', and, described in detail elsewhere (Chapter XVI), consists of the liberation of bubbles of nitrogen into the joints causing pain of varying degrees of severity (*see* Fig 92) and, in severe cases, partial paralysis

**2. Pressure on the Ears.**—Fortunately the mechanism of the ear permits of sudden lowering of pressure without more than passing discomfort (*see Fig.* 97). The reverse does not hold true, however, on subsequent descent, when atmospheric pressure increases (*see Fig* 99) Therefore, no damage or pain to the ears will occur at the moment of explosive decompression although the equalization of pressure in the ear will be clearly felt. If, however, height is subsequently lost rapidly, symptoms of transient pain and deafness of varying degree may occur exactly as when landing These difficulties can be dealt with in one of several ways described in the chapter on that subject (Chapter XVIII)

**3. Intestinal Distension.**—The volume of intestinal gases at 30,000 ft is approximately four times that at sea-level (*see Table* XIX, p. 206) Thus a sudden change of pressure may result in acute abdominal distension, and when this occurs, as it will when the atmospheric pressure is suddenly lowered, it may cause varying degrees of pain of a griping nature which can, however, in almost all cases, be easily relieved by the expulsion of wind In a few rare cases pockets of gas may become temporarily imprisoned in loops of the intestine, resulting in acute pain, but no serious injury will result and the condition will quickly be eased when lower levels are reached

**4. Anoxia.**—This is the major problem which has to be faced in explosive decompression, and is a matter for immediate and urgent action The effects of sudden deprivation of oxygen as occur in these circumstances differ in different individuals and under different circumstances Thus anything from mild discomfort to sudden death may occur. An individual's response under such circumstances varies according to his physical fitness, age, the presence of organic disease, the height at which the accident occurs, and the degree of decompression to which the person is subjected, as well as other less obvious factors. Thus, an abnormal consumption of alcohol or tobacco will considerably reduce an individual's resistance to oxygen lack It is thus not possible to elaborate the exact effects of oxygen lack on particular groups of individuals by reference to age, sex, occupation or specific diseases as there are so many variables to be considered, particularly where a public carrier is concerned. An accurate generalization may, however, be made between the effects on :—

*a* *Physically fit persons*

*b* Physically unfit persons

By physically fit persons is not meant outstanding athletes, but persons in a normal state of health, ranging through all ages from childhood to early old age By unfit persons is meant people

suffering from organic disease, particularly those diseases associated with the heart or lungs, and persons at both extremes of life, namely, newborn infants and the extremely aged Even in these latter cases no hard and fast rule can be drawn because, as is well known, one person of seventy-five may be in a much better physical condition than another ten years younger

The difference in effects of anoxia on the above-mentioned classes of individuals is merely that of degree, the symptoms being identical in all cases Thus the physically fit person will notice symptoms of oxygen lack later, his system will be able to compensate better, and his subsequent recovery will be more rapid The unfit person on the other hand will swiftly deteriorate, will be unable to compensate adequately, and may succumb rapidly without warning if untreated If treated, recovery may be slow

## EFFECTS OF OXYGEN LACK ON MAN

The effects of oxygen lack on man are progressive and the following sequence of events takes place They have been described elsewhere in the text, but are recapitulated briefly for convenience

**1. The Brain.**—This is the first organ attacked There is defective judgement, and lack of discrimination and perception There may be hilarity and a spurious sense of well-being, not unlike the early stages of alcoholic intoxication Self-criticism is lacking, there is carelessness in the performance of simple tasks and in general a diminution in all perceptive faculties Without appreciable warning, collapse and unconsciousness supervene followed by death if untreated

**2. The Eye.**—Visual acuity is reduced, night vision dramatically so, the particular cells responsible for night vision being especially susceptible to oxygen lack

**3. The Heart.**—There is a raised pulse-rate in an attempt to compensate for the lowered oxygen supply the body is receiving, but as this fails adequately to compensate for the situation, a feeling of dizziness and faintness precedes unconsciousness and later death A feature of the condition is that it may occur with practically no warning whatever Thus, a pilot may be in full possession of his faculties one minute and in few moments be unconscious This has been demonstrated in pressure-chamber experiments

**4. The Lungs.**—There is dyspnœa and air hunger, and the diminished oxygen supply to the lungs results in decreased oxygenation of the blood, with blueness of the lips and the extremities

## TIME AVAILABLE BEFORE UNCONSCIOUSNESS SUPERVENES

This varies directly with the height as is shown by *Fig* 89 (p. 180). From this it will be seen that at 20,000 ft, ten minutes will elapse before serious signs manifest themselves, whereas at 30,000 ft not more than one minute is available, and in two minutes at this height a person will be unconscious If such a situation is prolonged death will result.

## EXPERIMENTAL OBSERVATIONS

**1. General.**—Experiments on animals were first conducted in order to ascertain the effects produced by a sudden reduction in atmospheric pressure as would occur when a sealed pressure cabin was fractured at altitude The problem became much more acute in wartime owing to the increased liability of pressure-cabin aircraft to damage from enemy action In these experiments it was found that small animals suffered less than large ones, but no gross pathological abnormalities were discovered, and apart from slight signs of engorgement there were no striking post-mortem findings

Experiments on man have been conducted with two interconnected pressure chambers exhausted to a differential pressure of 5 lb per sq in, in which, by means of a controllable port, sudden decompression could be effected The speed of ascent used was between 34,000 and 36,000 ft per second, which it was estimated would be a greater pressure change than that caused by a 12-in square hole made in a pressure cabin at that height

**2. Symptoms.**—The following effects were noticed, and the measures taken to deal with them were as indicated —

*a Anoxia*—This was controlled by the application of 100 per cent oxygen up to about 35,000 ft

*b Decompression Sickness*—This was unlikely if oxygen had been used for some time prior to attaining altitude, and in any case was immediately relieved on losing height.

*c Respiration*—At the time of decompression there was a feeling of air being blown into the chest, but this was not painful and did not occasion any great discomfort About six hours later there was slight retrosternal pain, and the expectoration of a small quantity of mucus Other than that there were no untoward symptoms Such symptoms as those described might well be caused by a minor degree of trauma to the lung tissues Repetition of explosive decompression followed by severe exercise resulted in dyspnœa, cough, and expectoration. These symptoms quickly

passed off, however, and no other discomfort was noticed the following day.

*d Abdomen.*—There was immediate distension of the abdomen, easily relieved by belching and the passage of flatus; it did not usually cause more than passing discomfort.

*e Cardiovascular System.*—Electrocardiograms taken during the experiment showed no deviation from normal.

*f Sinuses and Ears.*—There was an immediate feeling of concussion at the time of the decompression, but forcible clearance by Valsalva's method was effective in obtaining equalization. Later on there was slight pain in the drums which quickly passed off.

**3. Conclusions.**—The maximum change of pressure was 5.8 lb. per sq. in., the maximum pressure ratio 2.4 to 1. This represented a maximum altitude change of 10,000 to 30,000 ft., or 25,000 to 44,000 ft. In no cases were any serious demonstrable effects noted, and subsequent observations in cases of damage inflicted upon pressurized aircraft at height have confirmed this view.

## SUMMARY AND CONCLUSIONS

From the above considerations it will be seen that following on explosive decompression the first essential is to provide crew and passengers with oxygen at the earliest possible opportunity. This can be done either by the provision of suitable oxygen apparatus or by descending to safe oxygen height, i.e., 10,000 ft. or lower. Provided oxygen is obtained by one of these methods, within the time limits laid down, no untoward effects will persist and recovery will be swift and complete.

The persons for whom the most immediate treatment is necessary are the crew members, and in particular the pilot, so that errors in judgement during the interim period of oxygen lack may be prevented. The symptoms experienced by passengers will not affect the safety of the aircraft as a whole.

## RECOMMENDATIONS

The following recommendations are submitted as being essential for safe operation when such an eventuality as explosive decompression is liable to arise. First, the route should, if possible, be arranged that a height of less than 10,000 ft. can be quickly attained and the remainder of the flight carried out at that height if necessary. Secondly, an emergency oxygen supply for all crew members should be available during the interim period, while safe oxygen height is being reached. Thirdly, emergency oxygen

supplies for a percentage of passengers (15–20 per cent) should be provided in the cabin, to deal with the small number in every ship's complement who may come in the category of unfit persons. Such persons are those with heart or lung trouble, or at either extreme of age. These measures should be adequate to deal with isolated cases whereby an invalid passenger, particularly susceptible to oxygen lack, succumbs without warning.

One point of practical importance where passengers are carried is that alarm may be occasioned by the formation within the cabin, when explosive decompression occurs, of a thick mist of condensation which might be mistaken for smoke from a fire. This, coupled with the aircraft's sudden descent, might upset some passengers, and stewards should be instructed to reassure passengers on this point in the event of such an accident occurring.

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*CHAPTER XV*

## OXYGEN POISONING

### GENERAL

WHEN respiration at increased pressures occurs, as in pressure breathing in aircraft, or when using divers' suits, inhalation of oxygen is of greater value than inhalation of air, because the use of air involves a great wastage in exhalation and the building up of dangerous nitrogen tensions

It has been known for many years that the human frame is relatively intolerant to increased tensions of oxygen, but the precise reasons for this were not known, nor were many details available as to the exact pressure at which symptoms were evident At sea-level there is an oxygen tension of approximately 159 mm Hg, and a tissue oxygen tension of 20-40 mm Hg, greater pressures than these are not met with under normal circumstances

The original work of Paul Bert with regard to increased oxygen tensions has stood the test of time He demonstrated that birds submitted to high air pressures died as a result of pulmonary damage At a later date Bornstein demonstrated that clonic spasms, amnesia, and confusion occurred as a result of breathing air at a pressure of three absolute atmospheres for 45 minutes Some cases, however, have been observed to suffer no ill effects at pressures up to seven absolute atmospheres

### OBSERVATIONS

A wide range of observations indicate that the most striking feature of this condition is the profound variation in the reactions of different subjects to increased oxygen tensions There are variations in time of onset, in severity of reactions, and in symptoms, and there appears to be little or no relation to time of exposure, age of patient, exercise indulged in, alcohol intake, smoking, or concentration of oxygen which, in very few cases, is higher than 95 per cent

It is apparent that there is very much less reaction to breathing oxygen under increased pressures above water than under water,

the cause of which is not known at present It is not considered to be due to increased carbon-dioxide tension

## SYMPTOMS

One of the first symptoms observed is twitching of the lips, and at the same time the subject complains of tingling in the fingers and toes, excitement, dizziness, photophobia, and other visual disturbances In addition, substernal pain, rhinitis, pharyngitis, and pulmonary damage have been reported There is usually pallor and an increased respiration rate, and there may be attacks of dyspnœa. The subject may be somnolent and depressed, or hilarious and euphoric , this is particularly marked in the terminal stages, when convulsions and incontinence lasting from a few seconds to a few minutes occur There are no significant changes in the blood, except for a transient lowered erythrocytogenesis

## FACTORS INFLUENCING EFFECTS OF OXYGEN POISONING

The following factors affect the reactions of the body to high oxygen tensions —

1 Hyperthyroidism increases sensitivity to the condition and hypothyroidism decreases it

2 Moderate variations in temperature appear to have no effect on the condition, but extremes of heat and cold increase sensitivity

3 Drugs which depress the metabolism of cortical activity delay the onset of convulsions, while convulsive drugs accelerate the condition

4 The time of onset of symptoms is made earlier by work

## RECOVERY

The condition quickly disappears when the subject is turned on to air, although in some cases this action may result in precipitating a convulsion This is thought to be due to a sudden *lowering of* the oxygen tension in the tissues Following the attack there is confusion, headache, and a certain degree of amnesia, not unlike the after-effects of an epileptic attack

## EFFECTS ON BODY SYSTEMS

**1. Respiratory.**—Lorraine-Smith states that no lung damage occurs at tensions which produce symptoms in other systems, and this has been confirmed by other observers

**2. Central Nervous System.**—In animals it has been demonstrated that the brain is the first part of the central nervous system to be attacked and the effects on it are thought to be due to the inhibition of pyruvic oxidase, or a poisoning of the carbohydrate oxidative process At a later stage the spinal cord and peripheral nerves are affected Electro-encephalograms are not significant

**3. Cardiovascular System.**—The blood-pressure is raised and the pulse-rate increased

**4. Other Organs.**—The liver, testis, kidney, lungs, and muscles are subsequently affected in varying degrees

## CONCLUSIONS

There are many dangers arising when breathing oxygen under increased conditions of pressure These are, however, very much greater under water than in the air, and the onset of symptoms under conditions of pressure met with in flying is unlikely Symptoms are thought to be caused by a high oxygen tension in the tissues, rather than by denitrogenation, and the inhalation of 100 per cent oxygen is not harmful if it is not under pressure

No warning symptoms can be quoted as specific as there is a great variation in their time of manifestation, appearance, and mode of onset Great care should, therefore, always be exercised when an attempt is made to increase the oxygen supply to the tissues by these means

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*CHAPTER XVI*

# DECOMPRESSION SICKNESS

## AETIOLOGY

THIS term is used to include a number of symptoms which occur when the human body is exposed to the low barometric pressures existing at high altitudes.

Although the pathogenesis of decompression sickness is fundamentally the same as that of caisson disease, there are three important differences between the two conditions which make the symptoms which occur in aviators much less severe than those observed in compressed-air workers. In the first place, the mass of nitrogen dissolved in the tissues of a diver working in four atmospheres pressure, at a depth of 100 ft, is four times as great as the amount dissolved in the tissues of an aviator, who starts all his flights from ground level. When the diver returns to the surface there is, therefore, four times as much nitrogen available for the formation of bubbles as there would be in the aviator if he made a rapid ascent to 35,000 ft., even though the ratio of the initial to the final pressure would be four to one in both cases. Another important factor in the aviator's favour is that he is always breathing oxygen when flying at high altitudes, therefore, his alveoli are filled with a gas containing very small quantities of nitrogen, and the resulting pressure-differential between the nitrogen-supersaturated blood and the practically nitrogen-free alveolar air increases the rate at which nitrogen passes from the blood into the expired air, thus reducing the amount of nitrogen available for the formation of bubbles. Finally, there is the fact that diver's 'bends' only occur after return to the surface, and treatment requires recompression which may involve considerable delay, or which may not be possible at all under existing conditions. The aviator, on the other hand, experiences symptoms of decompression sickness while flying at high altitudes, and he can immediately obtain complete relief of all the symptoms merely by decreasing the altitude a few thousand feet. While a diver may, therefore, suffer from excruciating pain and paralysis for several days as the result of an attack of the 'bends', an

aviator need never experience more than the earliest symptoms of decompression sickness, and these he can terminate without external aid, as soon as he notices the slightest impairment of his efficiency.

The following discussion of decompression sickness will be limited to altitudes below 45,000 ft., since this is the practical upper limit of human flying in non-pressurized aircraft. This limit is imposed by the fact that the barometric pressure at altitudes above 45,000 ft. is so low that disabling anoxia occurs even when one is breathing 100 per cent pure oxygen.

A great deal of confusion has been caused by attempting to apply the results of animal experimentation to the problem of decompression sickness in humans, because it was not generally recognized that the fatal air emboli which can be produced in animals exposed to pressure corresponding to 60,000 and 70,000 ft., depend on an entirely different mechanism from the relatively mild symptoms produced by the nitrogen supersaturation which occurs in humans at altitudes below 45,000 ft. The amount of gaseous nitrogen in the blood is 0.9 c.c. per 100 c.c. of blood, and only this small quantity of gas is available for bubble formation below 45,000 ft. 100 c.c. of blood also contains, however, 50 c.c. of carbon dioxide in chemical combination as bicarbonate, and 20 c.c. of oxygen in chemical combination as oxyhæmoglobin, and all of these gases may be liberated by pressure corresponding to 60,000 and 70,000 ft., although the chemical linkages are not disturbed at altitudes below 45,000 ft. In the animal experiments, therefore, there is the possibility of evolution of 75 c.c. of gas per 100 c.c. of blood, as compared with a maximum of only 0.9 c.c. in exposures of humans to altitudes below 45,000 ft.

In the production of the symptoms of decompression sickness the nitrogen dissolved in the tissues is just as important as the gas dissolved in the blood. The body of an average man weighing 60 kg. contains about 800 c.c. of dissolved nitrogen, of which 40 c.c. is in the blood, about 360 c.c. in the non-fatty tissues, and about 400 c.c. in the fatty tissues, such as the subcutaneous and intra-abdominal fat, the spinal cord, and the bone-marrow. The relatively large proportion of total nitrogen which is present in the fatty tissues is explained by the fact that the solubility of nitrogen in fatty tissues is five times as great as in non-fatty tissues. It has already been pointed out that the only way in which the body can get rid of excess nitrogen is by breathing it out through the lungs, and this process is greatly accelerated by breathing pure oxygen. It is obvious that the nitrogen dissolved in the blood will be eliminated very rapidly, since it is in intimate contact with the

alveolar air during its passage through the pulmonary capillaries The other tissues of the body get rid of nitrogen by diffusion into the blood which circulates through them, and on that account one would expect a higher rate of elimination from tissues with the best blood-supply. The rate of nitrogen elimination from fatty tissues will, therefore, be extremely slow, not only because of its high nitrogen content, but also because of the relatively poor circulation through most fatty tissues To emphasize these facts, let us consider the rate of elimination of nitrogen from the body of an average 60 kg. man when he breathes pure oxygen while seated at rest at ground level

It takes two or three minutes for the oxygen to replace all the nitrogen which was originally present in the alveolar air, but as soon as the alveoli become filled with oxygen, it only requires another minute or two before the entire 40 c c. of nitrogen in the blood is eliminated Nitrogen immediately begins to pass from the tissues into the blood, and out into the expired air, so that at the end of 15 minutes about one-half of the nitrogen in the non-fatty tissues has been eliminated; during the same time, however, only about 50 c c of the fat-nitrogen will have been given up At the end of the first hour the non-fatty tissues have been rendered practically nitrogen-free, but only about one-third of the fat-nitrogen has been given off The rate of liberation of nitrogen from fat is so slow that at least six hours of oxygen breathing are required for its complete elimination

The most rapid aircraft ascents, at present, make the formation of free nitrogen bubbles in the blood-stream extremely unlikely, due to the speed with which the nitrogen in the blood is eliminated. Nitrogen bubbles may, however, be expected to occur in the tissues, especially in those which have a relatively poor blood-supply in relation to their nitrogen content. The correctness of this deduction has been verified by X-ray studies of the location and rate of formation of nitrogen bubbles in various tissues of humans exposed to low barometric pressures in the decompression chamber A brief summary of these radiological studies of gas formation in tissues is as follows —

The commonest site of bubble formation is in the synovial cavities of the joints Bubbles occur less frequently in the synovial sheaths of the tendons, and occasionally in the subcutaneous fat [illegible] the peritoneal, [illegible] spinal fluid, and theoretically one would expect them to occur in the fatty bone-marrow, although they cannot be detected radiologically

Microscopic bubbles may be detected by X rays as low as 18,000 ft. (*Fig.* 92), but at this altitude they are very small even after exposures of several hours. As the altitude increases, the number,

*Fig.* 92.—Radiographs of nitrogen bubbles in the veins of experimental animals produced by ascent to high altitudes. (*From "Aviation Medicine," by H. G. Armstrong.*)

size, and rate of formation of bubbles also increase, so that at altitudes above 30,000 ft. bubbles may be found in almost all the joints of every subject on every flight which lasts more than a few minutes. It must be emphasized, however, that in the great majority of

cases the presence of bubbles is not accompanied by pain or any other symptoms, even when the gas is present in amounts sufficiently great to be detected by the crepitus produced on palpation Nor is there any correlation between the number, size, and location of the bubbles, and the location or intensity of the pain in those subjects who do have symptoms This does not indicate that the bubbles are not the primary cause of the symptoms, but merely that the production of symptoms requires, in addition, certain *local predisposing causes in the affected joint.* The nature of these local predisposing factors has not yet been discovered. The bubbles tend to increase in size as the duration of the flight is increased up to four or six hours; thereafter the gas is slowly reabsorbed as the nitrogen of the body is completely eliminated by the prolonged breathing of oxygen During descent the size of the bubbles decreases as the result of both recompression and reabsorption, and it is very difficult to detect gas by X rays on arriving at ground level, even after a descent from 40,000 ft in less than one minute

## SYMPTOMS

The following symptoms are produced in decompression sickness —

**1. Joint Pain.**—This is by far the most important symptom. It seldom occurs below 30,000 ft. except in unusually susceptible individuals, *but above this altitude the incidence and severity of pain tends to increase as either the duration or the altitude is increased.* Increasing the rate of ascent from 500 to 5000 ft. per minute produces a relatively unimportant increase in the incidence of joint pain The joints most frequently affected are, in descending order of frequently, shoulder, knee, wrist, elbow, ankle, and hip. The location of the pain at the time of onset is usually in, or adjacent to, one of these joints, but *occasionally it is definitely localized* to the substance of a muscle, and on rare occasions seems to follow the distribution of a peripheral nerve. The onset is usually gradual, but in a few cases is acute, and seems to be related to some sudden movement of the limb The pain usually begins as an indefinite feeling of stiffness, and later becomes a dull ache which is difficult to localize exactly, and which tends to wax and wane as time goes on Movement of the *limb almost always* aggravates the condition, but in rare instances a sudden movement may relieve it Increasing the altitude always makes the pain worse, but even at the same altitude the majority of pains will increase in severity as the duration of the flight is increased As the severity

of the pain increases, there is also a tendency for it to spread both proximally and distally to involve the adjacent muscles, and eventually the neighbouring joints, so that the whole limb is affected. Almost complete loss of function of the whole limb may occur as a result, not only of pain, but also of the reflex splinting of the affected muscles. In the later stages tremor and sustained clonus of the limb may occur. There are usually no objective changes in the colour, temperature, or measurements of the affected part. If the pain is borne by an effort of will-power after it has become very severe, systemic collapse with pallor, nausea, sweating, weakness, and eventual unconsciousness will occur. Pilots must, therefore, be warned that it is stupid rather than heroic to attempt to endure the pain to the limit of their tolerance. The pains are relieved almost instantaneously by descent. A mild pain may disappear after descent of 1000 to 3000 ft, a moderately severe pain may require 5000 or 10,000 ft, and a very severe pain may not be completely relieved until an altitude of 10,000 ft or less is reached. Very rarely a residual ache may remain even after descent to ground level, but no organic changes and no lasting impairment of function have ever been observed, even in subjects who have been exposed to repeated severe attacks of high-altitude joint pain. If a subject has had joint pain on one flight there will usually be a recurrence if he returns to the same altitude within the next few hours, but after a delay of 24 hours he is just as likely to be free of pain or to have pain in a different joint.

Susceptibility to joint pain varies markedly from one individual to another, but in spite of intensive investigation the factors which determine susceptibility have not been discovered. As a general rule, to which there are numerous exceptions, susceptibility seems to be greater above the age of 30, and in subjects who are overweight. Pain also seems to occur more frequently in joints which have been the site of old or recent trauma. Absolute immunity to joint pain seems to be extremely rare; almost everyone will be effected sooner or later if flights are frequent enough, and at sufficiently high altitudes, for sufficiently long periods. In healthy young men who meet aircrew medical requirements, about 30 per cent would be classed as relatively immune to joint pain, 50 per cent would have average susceptibility, and about 20 per cent would be considered unusually susceptible. This latter group shows a tendency for the pain to occur in the same joint in each individual on every flight, while the subject of average or above average tolerance may experience pain in almost any joint in the body at one time or another. Usually only one joint, but occasionally two or more, may be affected on the same flight. Since the factors

which determine susceptibility are not known, the only practical method of selecting aircrew for high altitude flying is by subjecting each candidate to a series of exposures in the decompression chamber. A fairly accurate estimate of an individual's susceptibility can be made on the basis of three or four runs of one or two hours each in the decompression chamber at an altitude of 35,000 ft.

**2. Gastro-intestinal Symptoms.**—Expansion of gases in the intestines produces distension of the abdomen, which is usually noticed at altitudes above 25,000 ft, but which seldom causes more than slight discomfort. Occasionally, however, the distension is great enough to cause abdominal cramps, and in rare instances may even interfere with the movement of the diaphragm. At one time it was thought that certain so-called gas-forming foods should be avoided in the diet of people flying at altitude, and that activated charcoal should be taken to absorb excess gas. This, however, has proved to be unnecessary, as individuals vary in their reactions to gas-forming foods, and anyone who is not extremely constipated finds no difficulty in eliminating excess gas from the anus. The relative volumes of gastro-intestinal gases at various altitudes are shown in *Table XIX*.

*Table XIX*.—THE COMPARATIVE VOLUMES OF THE GASTRO-INTESTINAL GASES AT VARIOUS ALTITUDES

| ALTITUDE | RELATIVE GAS VOLUME |
|---|---|
| ft | |
| 0 | 1.0 |
| 7,744 | 1.5 |
| 17,962 | 2.0 |
| 27,452 | 3.0 |
| 33,705 | 4.0 |
| 38,389 | 5.0 |
| 42,151 | 6.0 |
| 45,352 | 7.0 |
| 48,230 | 8.0 |
| 51,058 | 9.0 |
| 52,909 | 10.0 |

The symptoms which accompany this increased volume are:—

*a*. Inordinate abdominal distension.

*b*. Hypermotility of the abdominal organs.

*c*. Belching and the passage of flatus.

*d*. Pain. This is thought to occur when the gas becomes imprisoned in the loops of the small intestine.

**3. Paræsthesiæ** of various kinds are common symptoms of decompression sickness and are more annoying than serious.

Subjects may complain of itching, prickling, or burning sensations which seem to flit from place to place over the skin. Like any other itch, these paræsthesiæ are aggravated if the subject gives way to the desire to scratch the affected areas. They are also made worse by physical exertion, which causes the body to become overheated. The paræsthesiæ are presumed to be due to the presence of minute nitrogen bubbles in the subcutaneous fat, or in the vicinity of the nerve-endings in the skin. There is also a considerable psychogenic factor, especially in those subjects who complain of hot and cold waves which appear to travel over the body.

**4. Skin rashes** are relatively uncommon, and seem to be related to the paræsthesiæ. They usually, but not invariably, occur in overweight subjects who have experienced very severe itching or formication, especially if they have given way to the desire to scratch the affected areas, or if the circulation through the skin has been slowed by chilling of the body surface. The usual sites are the anterior abdominal wall, and the chest wall. The rash is a subcutaneous punctate or pericapillary ecchymosis, which may become confluent so that it resembles the early stages of post-mortem lividity. The affected area may be slightly tender, but the rash usually disappears in twelve to forty-eight hours and leaves no residual effects. Traumatization of the capillaries by the presence of nitrogen bubbles, combined with the effect of scratching, is presumed to be the cause. Much more rarely, rashes of an urticarial nature have been observed. Subjects who develop rashes should not be detailed for high-altitude flying.

**5. Otitic Barotrauma.**—This is considered separately in Chapter XVIII.

**6. Anoxia.**—This is the subject of a separate chapter (Chapter XIII).

**7. Cardiac and respiratory symptoms** are surprisingly rare. In the absence of anoxia there are no changes in the pulse-rate, blood-pressure, electrocardiogram, or in the size of the heart, as determined by radiograph. The only symptom referable to the thoracic cavity is a sensation of 'tightness' in the chest which is usually noticed in flights over one hour's duration or at altitudes above 35,000 ft., especially when the ascent has been unusually rapid.

This unpleasant sensation which seems to interfere with breathing is usually first noticed in the suprasternal notch and later spreads down substernally along the course of the trachea and bronchi. It is often brought on by, and always aggravated by, any physical exertion which increases the rate and depth of respiration. When

the discomfort becomes severe the subject finds it impossible to take a deep breath, and the interference with normal respiration at such high altitudes quickly leads to the development of anoxia, which in turn produces systemic collapse and loss of consciousness unless the altitude is decreased. A mild degree of substernal discomfort on deep inspiration may persist for several hours after return to ground level There may be an accompanying slight cough, but there is usually no sputum This disquieting and potentially dangerous symptom may be due to the presence of nitrogen bubbles in the lungs, but the evidence at the present time is inconclusive The only safe rule is to warn pilots against undertaking more than an absolute minimum of physical exertion when flying above 30,000 ft, and to return to a lower altitude as soon as any signs of substernal discomfort are observed

**8. Neurological symptoms** might be expected to occur at high altitudes in view of the prominent role which they occupy in the syndrome of caisson disease There have, however, been only a very small number of reports of symptoms which may have been due to the presence of nitrogen bubbles in the central nervous system, and most of these reports are probably due to the effects of an accidental unnoticed anoxia, which may so easily occur in experiments at very high altitudes Headaches of a migrainous nature have been reported occasionally, accompanied by visual disturbance of uncertain aetiology. Most, if not all, of the few cases of 'paralysis' which have been reported, are the result of the complete loss of function which is produced by pain and splinting of a painful joint, and most of the reported instances of loss of consciousness are probably the results of vasomotor collapse resulting from autonomic reflexes set up in a painful joint If anoxia does not occur, psychological tests of the higher mental functions demonstrate no impairment after exposures of as long as twelve hours at 30,000 ft, or six hours at 35,000 ft. Chronic mental symptoms such as irritability and insomnia were described by the earlier investigators of this problem as occurring for several days or weeks after exposure to low pressures in the decompression chamber, and these symptoms were thought to be due to the presence of nitrogen emboli in the central nervous system It is now generally recognized that these symptoms were merely manifestations of an anxiety neurosis which developed in the early volunteers, who had been led to believe that the experiments were infinitely more hazardous than subsequent events have proved them to be

**9. Symptoms referable to the renal system** have not been observed

**10. Biochemical and hæmatological studies** have not demonstrated any effects on the blood chemistry or the hæmatopoietic system as a result of repeated exposure to low barometric pressure

**11. Voice Changes.**—There is a noticeable change of pitch in all voices over 25,000 ft, the precise cause for which is not understood It is probably associated with a change in the density of the air at that height

**12. Dental Pain at Altitude.**—Gaseous expansion in the pulp of defective teeth at higher altitudes may cause severe odontalgia, and in addition, if fillings of the wrong *p*H are used, a similar condition may occur Another possible cause is the generation of too great heat near the pulp when drilling is taking place prior to stopping

## TREATMENT

**1. Prophylactic.**—The obvious approach to the problem of prophylaxis is to discover some way of removing the nitrogen from the tissues before ascending to high altitudes It has already been pointed out that this can be done by having the subject breathe pure oxygen at ground level for some hours before flight Since this procedure is obviously impracticable, an attempt has been made to hasten the elimination of nitrogen by having the subject breathe oxygen while exercising, in the hope that the increased circulatory rate would remove nitrogen from the tissues more efficiently. Exercise does increase the rate of nitrogen elimination very considerably, and relative, but not complete, immunity can be secured, by oxygen breathing, and exercise for 30 minutes, even this short period is not yet regarded as practicable in military aviation

**2. Curative.**—It should be clear from what has already been stated, that the simplest cure for all the manifestations of decompression sickness is to return to a lower altitude No other form of treatment by physical means or by drugs has yet been discovered

## CONCLUSIONS

The present practical compromise solution to the high-altitude problem is to use personnel who have been selected by decompression chamber tests, since it has been shown that such men can function efficiently for several hours at altitudes between 30,000 and 35,000 ft and for shorter periods even up to 40,000 ft

With pressurized aircraft the condition is becoming increasingly rare.

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## CHAPTER XVII

# AIR-SICKNESS

### DEFINITION

Air-sickness may be defined as a condition due principally to vertical accelerations or excessive rotary motions occurring in aircraft flights It is analogous to car-, train-, or sea-sickness, and might be referred to simply as motion sickness Armstrong considers that air-sickness is a temporary, functional neurosis, the primary cause being accelerations, which bring conflicting sensory impressions of orientation and equilibration to the mind It is not easy to state with certainty how great a problem it constitutes

tend to diminish rather than increase It represented a small but ever-present problem in military flying, which required elimination of intractable cases at the training stage, and treatment of occasional sufferers on operations, whose military flying duties were noticeably interfered with by the condition In straight and level flight it does not present a great problem It has been estimated that in flights of two hours or longer about 17 per cent of people are air sick on their first flight, 40 per cent on their second, and 0·5 per cent continue to be sick persistently (Whittingham) A large majority of people liable to air-sickness on such occasions become acclimatized with repeated flying Its control and elimination, if possible, in both military and civil flying is a desirable objective to be arrived at in the interests of comfort and efficiency

### AETIOLOGY

Although a great deal of experimental work has been conducted with regard to the aetiology of air-sickness and motion sickness generally, it must be admitted that little progress has been made The cause is thought to be partly psychological, partly vestibular, and in part located in the cerebellar cortex, and lines of treatment

have been based on these assumptions. The truth probably is that several factors all play an important part in the aetiology of the condition It occurs among every known type of individual, under different circumstances, and every variety of flying conditions, and this has led to an imperfect and inaccurate evaluation of its true aetiology. The effect of motion on the labyrinth is probably an important factor, but tests usually employed by otologists have been unable to discriminate between those who are air sick, those who are not, and individuals who are otherwise normal; many

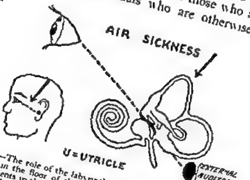


*Fig 93.—The role of the labyrinth in air sickness Excessive stimulation of the filaments in the floor of the utricle caused by pressure of the otolith organ due to movements in the vertical plane leads to nausea and air-sickness (By kind permission of Air Marshal Sir H E Whittingham )*

investigators are still at a loss to attribute any specific cause to the condition The labyrinthine factor in air-sickness is considered to be due largely to hypersensitivity and over-stimulation of the floor of the utricle by the otoliths (Fig 93). Thus, with the head in the normal sitting position vertical acceleratory movements, such as occur in bumpy weather, lead to variations in pressure of the otolith organs on the filaments of the utricle, which in their turn initiate the symptoms Certain distinguishable features, however, which have been confirmed by observation, are clear.

1 The severity of air-sickness depends upon the length of the flight and the roughness of the air.

2 The tendency to air-sickness varies greatly in different individuals, and the great majority adapt themselves fairly quickly to aircraft motion.

3 The presence of odours, poor ventilation, and too great heat or cold predispose to the condition

4 Indiscrimination in diet, alcohol, or inadequate rest, increase susceptibility to air-sickness.

5 Toxic foci have in several cases been shown to be a contributory factor, which when removed, quickly alleviated the

condition Infected tonsils and dental abscesses are included in this category.

6 Anoxia increases the liability to air-sickness, and many cases showing early signs of air-sickness can be aborted by increasing the oxygen supply

7 Motion Movement of the aircraft in the vertical, longitudinal, or lateral plane will induce air-sickness, even in calm weather, and the tendency of some aircraft to 'wander' in flight can be very productive of cases of air-sickness More noticeable movement such as steep turns or descents can have the same results, and during violent evasive action to avoid enemy fighters it was usual for the majority of bomber crews, however experienced, to be sick

8 Fixation of head It has been demonstrated that movements of the head and eyes relative to the body quickly induce air-sickness, and later, acute vertigo Prevention of this by the provision of suitably designed headrests with side cushions to prevent the head rolling from side to side, have shown encouraging results in selected cases

9 Take-offs and landings In many flights the greater part of the journey is carried out at heights where atmospheric conditions are largely stable, and no air-sickness will be experienced Turbulence is frequently encountered, however, when climbing up through bad weather to the predetermined flight level, or similarly when coming in to land, more often the latter Thus a long trans-oceanic flight may be entirely without incident until the last twenty minutes, when the aircraft is descending through cloud prior to landing, when many people may be air sick In addition to turbulence there are superimposed such factors as apprehension and excitement, all of which increase the liability to nausea

10 Psychological factors There is undoubtedly a large psychological element in air-sickness, which frequently makes it difficult to assess many of the other relevant factors at their true value. Fear and apprehension, both of which tend to produce nausea and vomiting in some persons under certain conditions on the ground, all increase the liability to the condition At the same time if the psychological element is recognized, autosuggestion and the [illegible]lation of a sense of confidence and peace of mind in the passengers can do much to ameliorate symptoms and relieve distress. Symonds and Williams found that neurosis is present in about 7 per cent of air-sick persons although a much higher percentage (40 per cent) have a neurotic disposition In their opinion these psychological factors lower the physiological threshold for tolerance to motion, or the will to endure premonitory symptoms and by so doing increase the liability to the condition

11. Vision. In some persons the sight of the wing moving in relation to the earth's surface can precipitate nausea, particularly when this is associated with the effect of acceleration forces acting as a result of the aircraft banking in a turn prior to coming in to land, at this time there is also a desire to look out and strain the eyes which further aggravates the condition.

## INCIDENCE

Experience in war has shown that in operational aircrew, rear-gunners and navigators suffered most, engineers and bomb-aimers to a lesser degree, while pilots suffered least There are several reasons for these variations.

*First*, the pilot, bomb-aimer, and engineer are usually located near the centre of gravity of the aircraft, and are therefore subjected to less movement in vertical or horizontal planes The rear-gunner, on the other hand, is in that part of the aircraft most subject to movement in all planes. In the case of the navigator, although he is also usually located near the centre of gravity of the aircraft, his duties entail working over a chart table with his head in that position which is most conducive to air-sickness, furthermore, he is constantly using his eyes for near vision in deciphering small figures or map details, and using radar and other visual navigational aids, all of which are contributory factors in increasing liability to the condition.

Another less important consideration is that the pilot is constantly occupied with manipulative procedure and general responsibility for the flight, while for other crew members, such as the rear-gunner, there may be long periods of mental and physical inactivity Mental occupation is helpful as a preventive, particularly if a psychological element is present.

## SYMPTOMS

These are almost identical with those of sea-sickness or train-sickness, and consist of pallor, sweating, nausea, vomiting, vertigo, and lastly prostration In extreme cases the pulse is feeble and thready, the systolic blood-pressure is lowered, and the respiration rate slightly increased

## PREVENTION AND TREATMENT

The following paragraphs indicate some accepted methods of dealing with the problem, based on present-day knowledge and experience

1. **Pre-selection.**—Subjects for aircrew training can be tested on a swing, but in practice this test has not been found to be very satisfactory, first because it produces a higher rate of sickness than is found in actual flying, and secondly because to date it has not been possible to reproduce accurately, on a swing, the movements that are met with in an aircraft. Thus, on a swing the movements tend to be too regular, of restricted travel, and in one or two planes only, whereas in flying every variety of angle and radius may be experienced. In a survey conducted among 2682 trainees the following factors were revealed:—

| | |
|---|---|
| Personnel reporting sick | 407 |
| Reporting air sick on more than one occasion | 106 |
| Days lost per case | 1 |
| Days lost in persistent cases | 4 |
| Cases who ceased training on account of air sickness | 13 |
| Results of varying forms of treatment | Nil |

In practice it has been found essential ruthlessly to eliminate persistent air-sick cases in the early stages, as they invariably give trouble at a later stage and are really never cured. On the other hand, a number of novices are initially sick, quickly overcome the condition, and will have mild recurrences on changing from one type of aircraft to another. They usually, however, quickly settle down.

In addition to swing tests, candidates for aircrew duties should be tested for air-sickness under actual flying conditions. In practice it has been found that a minimum of three flights, each of not less than three hours' duration, is desirable before a person's liability to air-sickness can be assessed with reasonable accuracy. Such flights should include experience of rough weather and certain deliberate manœuvres such as turns and banks, during which time the candidate will be required to carry out the duties which will be required of him in his work. The majority of cases suffer no ill effects other than a little nausea, due in part to apprehension and excitement, while others are sick at first but soon recover, and rapidly lose any feeling of malaise or discomfort. A small number, however, continue to be sick, or experience nausea the majority of the time they are airborne, and these should be eliminated from further flying training, as if not they will be a constant liability subsequently.

2. **Drugs.**—As in the case of sea-sickness, a great variety of drugs, and combination of drugs, has been tried with varying degrees of success, and the multiplicity of cures advertised is sufficient indication that no certain remedy exists. Of all drugs,

sedatives in the form of barbiturates, and the belladonna alkaloids *in various combinations*, appear to be the most effective. The one drug which is of unquestioned value is hyoscine hydrobromide Atropine and hyoscine act on three important points in connexion with air-sickness. the central nervous system, smooth muscle, and the secretory glands innervated by the post-ganglionic cholinergic fibres On all these the alkaloids act as a parasympathetic depressant There is a primary stimulation of the medulla and *higher cerebral centres, followed* by a sedative effect, indicated by drowsiness, an attitude of *laisser faire*, lack of apprehension, and, frequently, sleep. In some cases there is idiosyncrasy, resulting in excitement, and at times, delirium or mania Salivary and gastric secretion is diminished, the former noticeably so. The sedative effects of the barbiturate group used in conjunction with the belladonna alkaloids mentioned above form the basis of the most *successful remedies*

The introduction of benzedrine in some cases is stated to have a beneficial effect, and such a combination was used on operations in the Royal Air Force with success

Some of the combinations of the above drugs which have proved effective in practice are as follows —

| | | |
|---|---|---|
| *a* | Hyoscine hydrobromide - | $\frac{1}{200}$ gr |
| | Benzedrine sulphate | 2 mg |
| | Sodium phenobarbitone | $\frac{1}{8}$ gr |

Six tablets to be taken for each eight- or ten-hour flight. Two should be taken half an hour before flight, and two more at subsequent *three-hourly intervals Not more than six tablets* should be taken altogether One tablet should be taken to test for benzedrine idiosyncrasy before use.

Another compound which has met with considerable success is

| | | |
|---|---|---|
| *b* | Hyoscine hydrobromide | $\frac{1}{200}$ gr |
| | Atropine sulphate | $\frac{1}{200}$ gr |
| | Sodium phenobarbitone | $\frac{1}{2}$ gr |

The following formulæ are marketed under proprietary trade names and are used extensively by the travelling public

| | | |
|---|---|---|
| *c* | Ammonium bromide | 0 195 gr |
| | Potassium bromide | 0 195 gr |
| | Hyoscine hydrobromide | 0 216 mg |
| *d* | Lactose | 0 129 gr |
| | Hyoscine | 0 0638 mg |
| | Hyoscyamine | 0 235 mg |

One tablet to be taken before flight commences, and one at subsequent four-hourly intervals if required

*e* A form of medication favoured in America consists of $\frac{1}{150}$ gr. of scopolamine in a scented chewing gum l . acceptable

to passengers, and at the same time facilitates the opening of the Eustachian tubes as a result of the chewing required

*f.* In the case of aircrew, however, it is not desirable to introduce a sedative which might interfere with the efficient performance of their duties, and in such cases hyoscine hydrobromide used alone in the form of a sugar-coated pill is very satisfactory In such cases the effective dosage is $\frac{1}{100}$ gr One should be taken before flight, and subsequently in three hours' time if required

*g* Exceptionally good results have recently been claimed in America for a drug of the trade name of Dramamine (beta-dimethylaminoethyl benzohydryl ether 8 chorotheophyllinate) but sufficient experience with it has not yet been obtained to justify a considered opinion

There are many other permutations and combinations, all of which utilize the same essential ingredients in varying amounts, but to date no controlled scientific observations have been made on a sufficiently extensive scale to justify the exclusive recommendation of any particular remedy, as all recommendatio[ns] must be based on personal observations and a relatively limite[d] field of trial Furthermore, any such reports received must tak[e] into consideration the large psychological factor which is involve[d] in this condition at all times

**3. Diet.**—Fatty and greasy foods should be avoided in excess when flying, and some claim that ingestion of glucose helps to prevent nausea It is important in this connexion to ensure that small quantities of palatable foods are given at frequent intervals rather than heavy indigestible meals at long intervals This is discussed more fully under DIET (Chapter V), but it is found in many cases that passengers feel faint and nauseated if they are permitted to go for a longer period than two hours without food of some sort With some persons the result of lack of food is hypermotility of the stomach which increases any predisposition to air-sickness Persons should not be forced to eat, but food should be readily available in light and palatable form when required In particular there is a tendency for this precaution to be neglected during long flights by night, when some passengers are unable to sleep, and may become unwell as a result of lack of food over a long period of time

**4. Seat Positions.**—The problem of seating has received much attention in connection with the incidence of air-sickness, but as yet nothing positive has been evolved At one time it was claimed that backward seating resulted in a reduced incidence, but this has not been fully substantiated Extensive tests in America on the incidence of sickness in relation to particular seats in aircraft

have yielded interesting information. Those seats situated nearer the centre of gravity of the aircraft are less subject to turbulence and 'see-saw' movement in the longitudinal and horizontal plane, and are consequently less productive of sickness than those in the rear portion of the aircraft where movement is more marked In one series of cases investigated, the left-hand seats near the leading edge of the wing were those most productive of air-sickness The theory postulated for this distinction was that the standard practice in all commercial aircraft on approaching an airport is to carry out a left-hand circuit, and a person sitting in this seat would naturally be tempted to look out and see what was going on, and would receive visual impressions of the aircraft banking and turning, and the alteration in angle of the wing in relation to the ground, together with a changing terrestrial scene which was not visible to passengers sitting in other seats For reasons given in a previous paragraph, these visual impressions and movements of the eyes and head may well play an important part in inducing air-sickness

**5. Design of Chairs and Seating.**—Experience has shown that the tendency to air sickness is reduced if the seating accommodation can be so adjusted as to give maximum comfort, with as close a proximity to the completely recumbent position as possible. Furthermore, as mentioned in a previous paragraph, it is desirable to provide lateral cushions on the back-rest for the sides of the head, to prevent unnecessary movement of the head relative to the trunk A comfortable passenger in the completely recumbent position with the head still and the eyes closed is less liable to air-sickness than one sitting upright and with the head liable to movement Experiments with the Bárány chair have shown that repeated accelerated and decelerated linear or rotary motions alone are not nearly so productive of motion sickness as those produced by changes in the position of the head relative to the body during rotation Intense sickness is produced in a large number of subjects by this latter manœuvre The condition is less severe when it is possible to fix the eyes on an object which participates in all movements of the head

**6. Ventilation.**—Removal of exhaust and other odours from the cabin, and maintenance of an equable temperature of 60–70° F throughout is desirable at all times Desirable ventilating criteria are discussed in Chapter XI

**7. Psychotherapy.**—This factor plays its part by reassurance and encouragement, and an anxious or apprehensive passenger can be greatly helped in this respect

**8. Physical Fitness.**—Inadequate rest, the presence of septic foci, and other causes of lowered physical fitness may all be

contributory factors in the condition, and should be eradicated where possible.

**9. Oxygen.**—Anoxia may be a predisposing factor in the condition, and the inhalation of oxygen when premonitory symptoms occur frequently aborts the attack

## SUMMARY AND CONCLUSIONS

An assured remedy for air-sickness is not yet finalized, and doubtless further discoveries as to its aetiology will assist in treatment. The location of the receptor apparatus which initiates motion sickness is still not clear, but it is thought that the cristæ ampullares, as well as the maculæ, play an important part Its prevention and cure depend on attention to a number of related factors, including drugs, diet, cabin conditions, and the general comfort of the person concerned, as well as psychological factors such as freedom from worry and apprehension There is no panacea for the condition, and in the case of aircrew, intractable cases should not be allowed to continue training.

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## CHAPTER XVIII

# OTITIC BAROTRAUMA

## DEFINITION

This terminology is used to describe varying degrees of trauma which may be occasioned to the ear-drum and middle-ear by changes of atmospheric pressure which occur in flying. The condition is one which has given a great deal of trouble in high-altitude flying and is explicable on purely mechanical grounds. Prevention is the soundest method of dealing with it, as to date existing methods

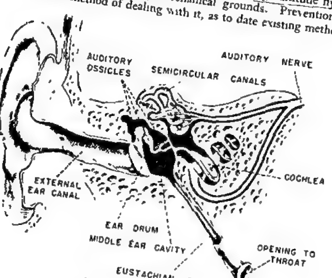

Fig 94 —Anatomy of the ear

of relieving the condition, once fully established, are usually accompanied by a prolonged recovery period, which varies according to the severity of the condition.

A brief review of the mechanism by which pressure changes in the middle and outer ear are equalized will not be out of place here.

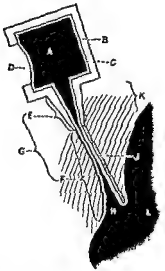


*Fig* 95 —Middle-ear [illegible]
ear C Mucou[illegible]
portion of Eust[illegible]
Eustachian tube [illegible]
plate of Eustach[illegible]
pharyngeal cavit[illegible]

*(Figs 95–102 —from 'Contributions to Aviation Otolaryngology,' by E D D Dickson and others, by courtesy of Headley Bros)*

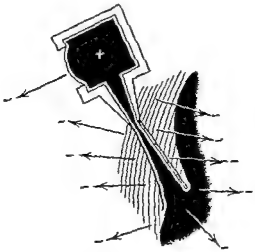


*Fig* 96 —Forces acting on middle ear on ascent

The tympanic membrane forms the lateral wall of the middle ear, and the opening of the Eustachian tube is on the antero-inferior side, from whence it runs downwards, forwards, and medially

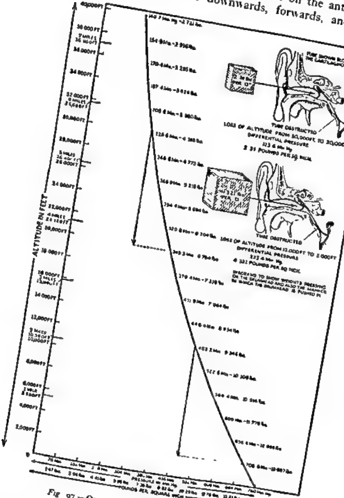


Fig 97.—Opening of Eustachian tube on ascent

to make connexion with the nasopharynx (*Figs* 94, 95). The Eustachian tube, partly bony, partly cartilaginous, and narrowest at the junction of these two parts, is lined with columnar ciliated

epithelium continuous with the pharynx. Arising from its medial, lateral, and inferior sides are the levator palati, tensor palati, and salpingopharyngeus muscles, all of which are inserted into the soft palate. As the extra-tympanic pressure decreases during ascent to altitude, the drum head gradually bulges outwards until at a pressure corresponding to approximately 435 ft. altitude (745 mm Hg) a click is heard and felt in the middle ear, and at the same time the tympanic membrane reverts to its normal position by

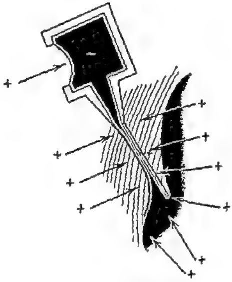

*Fig. 98.—Forces acting on middle ear on descent*

reason of the fact that air has escaped from the middle ear through the Eustachian tube to the nasopharynx. *This can be observed* with great clarity in a decompression chamber, and is illustrated diagrammatically in *Fig.* 96.

There are individual variations in this reaction, but one constant factor is that a compensatory opening of the Eustachian tube with its attendant equalization of pressure occurs every 435 ft. of ascent, irrespective of the curve of atmospheric pressure. (*Fig.* 97.) Closure of the Eustachian tube occurs almost immediately, leaving a positive intratympanic pressure of about 3.6 mm. Hg. Thus something more than this pressure is required to open the tube. With continued ascent, lesser positive intratympanic pressure is necessary to cause the tube to open.

Unfortunately this simple and painless procedure does not act in reverse upon descent from altitude Upon descent, the atmospheric pressure increases, but the intratympanic pressure remains the same, and consequently the drum head begins to retract inwards

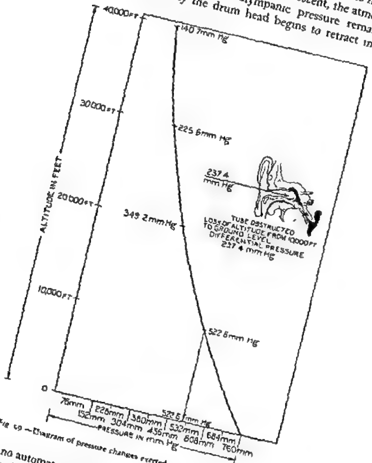


*Fig [illegible] —Diagram of pressure changes exerted on middle ear on descent*

There is no automatic compensatory opening of the Eustachian tube to permit the exit of air and equalization of pressure, and consequently, if allowed to persist, the drum head will retract more and more until it eventually ruptures (*Figs* 98, 99) Tension on the palatal muscles inserted into the walls of the tube caused by the act of swallowing or chewing will open the lumen of the tube (*Fig* 100).

and it is this action of auto-inflation which is the means whereby pressure changes outside the tympanic membrane are voluntarily equalized by a corresponding change inside.

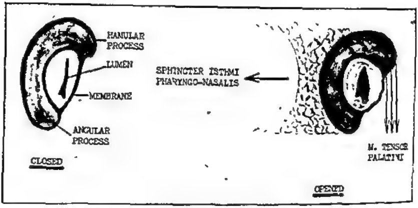


*Fig* 100 —Mechanism of tubal opening

## AETIOLOGY

Inadequate pressure equalization due to failure of the Eustachian tube to open, may occur under the following circumstances —

**1. In the Healthy Subject.—**

*a* By very rapid descent under the stress of operational duties when due to the attention of the subject being concentrated on other things, he is unable to perform auto-inflation

*b* Failure by the subject to understand the methods of auto-inflation

*c* During sleep

**2. Pathological Conditions.—**

*a* Temporary œdema of the Eustachian mucosa, as a result of infection spreading into the tube from the nasopharynx

*b* Chronic Eustachian obstruction resulting from infected tonsils, nasal polypi, or other causes of nasal obstruction.

*c* Permanent cicatrization of the Eustachian orifice as a result of repeated infection.

*d* Coma. A person in this condition is unable to exert the volitional effort required to open the Eustachian tubes

## SYMPTOMS

Otitic barotrauma is the nomenclature which has been adopted to describe this condition, and four clearly differentiated degrees of severity may be seen. There are, however, certain features

which, in varying degrees, are common to all stages of the condition, namely, pain, deafness, a feeling of fullness in the ears, and occasionally tinnitus and vertigo.

**1. Pain.**—This may be mild, amounting to little more than a feeling of fullness in the ears, or very severe, depending on the degree of negative pressure causing the condition, and upon the pain threshold of the individual. The pain is referred typically to the carotid area of the posterior angle of the mandible, and is commonly regarded as being due to alterations in the tension of the tympanic membrane, but stimulation of pain nerve-endings in the mucosa lining the middle-ear cavity is probably a more important factor. The characteristics of the pain are very similar to those produced by negative pressure in the frontal sinuses, in which a bony and mucosal wall only is involved.

**2. Deafness.**—Experimental occlusion of the Eustachian tube produces first and mostly, auditory impairment in the high-tone region, and later, slighter impairment for middle and low tones. Immediately after restoration of adequate ventilation of the middle ear, the hearing threshold for all frequencies returns to the values obtained before the experiment. This phenomenon may be one explanation of the variations in audiograms shown by different subjects who have experienced otitic barotrauma. The decrease in auditory acuity is the result of interference with the conducting mechanisms in the middle ear, and changes in relative angles of the ossicles, reducing the amplitude of vibration at the fenestra ovalis.

Rinne's test is negative, and in unilateral otitic barotrauma Weber's test is referred to the affected side.

**3. Tinnitus and Vertigo.**—This is occasionally present; tinnitus may persist after hearing has been restored.

## DIAGNOSIS

When the subject reports the above symptoms, which are characteristic, together with a history of sore throats or cold, the tympanic membrane is the only one of the structures involved which is accessible to easy examination. One of the five following degrees of trauma will be recognized.

*1.* A slight indrawing of the tympanic membrane with no hæmorrhage or wrinkling. The subjective symptoms in this case will be slight high-tone deafness, and fullness in the ear, but no pain.

*2.* Definite indrawing of the drum, and engorgement of the blood-vessels, usually in the posterior superior quadrant. There is moderate degree of pain and deafness.


A, Normal
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(*Drawn from actual cases by J E G McGibbon*)

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F

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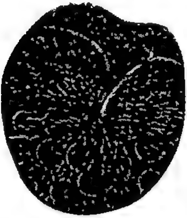

H

3 A considerable degree of indrawing of the drum with a ruptured leash of vessels in between the inner and outer layers of the tympanic membrane, severe pain and deafness.

4. Effusion, usually into the posterior compartment; this is not always immediately evident, due to hæmorrhage and œdema.

5. Complete rupture of the drum, which although it may have been painful at the time, may no longer be so.

In all the above cases there is inability to produce auto-inflation, either by swallowing or by Valsalva's method. Varying degrees of tympanic trauma are shown in *Fig.* 101.

## TREATMENT

**1. Preventive.**—

*a.* Education.—All aircrew should be regularly lectured, with demonstrations on a model ear, as to the methods of clearing the ear, and the anatomical and physiological features explained.

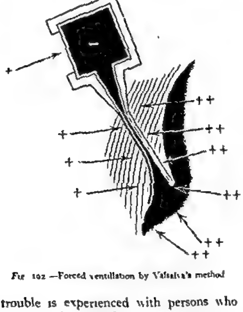


*Fig* 102.—Forced ventilation by Valsalva's method

Very little trouble is experienced with persons who have been properly instructed in this procedure

*b.* Auto-inflation.—The disability can be overcome by active, co-operation on the part of the pilot by means of auto-inflation, which is carried out in the following manner:—

*i. The first action is that of* swallowing, which in many cases produces a satisfactory opening of the tube.

ii An alternative method found by some to be more satisfactory is a rotatory movement of the lower mandible in the horizontal plane, an exaggerated form of chewing

iii If both these methods fail, auto-inflation by Valsalva's method should be used (*Fig* 102) It is important that this should be correctly performed, and the following points should be noted —

α The head and neck should be well extended. This is directly contrary to previously accepted practice when instructions were given to flex the head on the chest, but experience in many cases indicates that much greater ease in clearance is effected in the extended position

β. Secondly, the cheeks should not be puffed out, as in this case the advantages of raised pressure are largely lost where they are most required, namely, at the nasopharyngeal opening of the tube

γ. Thirdly, the pressure should be built up slowly, and not with violence, as the tube responds more readily to gradually increased pressure.

A greater change of pressure occurs between 10,000 ft and ground level than between 20,000 and 10,000 ft, and 30,000 and 20,000 ft, therefore auto-inflation is more necessary in the later stages of descent. In a healthy subject who has been adequately instructed, no difficulty is experienced in adjusting pressures in this way Where, however, by reason of obstruction to the lumen of the Eustachian tube, this clearance cannot be effected, trouble will occur. This is shown diagrammatically in *Fig* 95

*c.* Discipline —No person should fly at altitude in unpressurized aircraft who has a heavy cold or sore throat Whilst in many cases no harmful effects might accrue from this, and, in fact, aircrew often claim that their colds are better after flying, the amount of flying hours lost due to colds is infinitely less than those lost due to otitic barotrauma caused by flying with colds. The incidence of otitic barotrauma can be much reduced by compulsory grounding of all aircrew with a severe cold, wherever operational requirements permit.

*d* Elimination —Examination in a decompression chamber provides an excellent method of assessment of a person's aural fitness. Subjects who have a clinical history of previous attacks of earache, deafness, or aural discharge with objectively nonpatent Eustachian tubes should not be accepted for aircrew duties

**2. Curative.—**

*a.* Immediate.—

i *Re-ascent.*—Whilst the damage that has been done cannot be undone, the symptoms can immediately be relieved by ascending to altitude again, either in an aircraft or in a decompression chamber

ii *Auto-inflation* —Attempts may be made on the ground to auto-inflate the middle ear in the manner described earlier, this usually proves unsuccessful

iii *Politzerization*—This usually effects immediate relief of symptoms. Originally it was considered that this was a dangerous manœuvre in the presence of infection in the nasopharyngeal cavity, but experience has shown that this fear was unfounded, and no cases of infection of the middle ear have been reported as a result of this treatment.

iv *Eustachian Catheterization*—In extreme cases this method can be used, but requires the attention of a trained oto-rhino-laryngologist

v *Proetz's Method*—It is claimed by the author of this method that its employment reduces the time of recovery considerably. *Briefly it postulates that obstruction in the Eustachian tube is* caused by a mucous plug which may be easily removed by loosening it with vasoconstrictors, and subsequently withdrawing it by controlled suction with the displacement bulb.

vi *Myringopuncture*—Where equalization of pressure in the Eustachian tube fails, or is unsatisfactory, the following method of equalization by myringopuncture has been successfully practised with good results

The tympanic membrane is anæsthetized by the application of 10 per cent cocaine in aniline oil Complete analgesia is produced in 10 minutes (The anæsthetization is desirable but not essential, and in some cases the puncture is performed without any analgesic.) Needle puncture of the postero-inferior quadrant of the tympanic *membrane with a fine-bore, sterilized, bevel-point* needle, is then performed

Air is admitted directly to the tympanic cavity resulting in —

*a* Restoration of the drum to its normal position

*b* Immediate relief of pain.

*c* Restoration of hearing

Examination immediately after the operation shows no visible damage to the middle-ear structure, with merely a pin-*point of* serum to mark the point of entry of the needle. Repeated examination at further intervals shows no subjective or objective abnormalities The method is one deserving of serious consideration, is easy to perform, and accelerates recovery from acute otitic barotrauma.

*b* DELAYED —

i *Vasoconstrictors*—These may be used with varying success to hasten clearing up of a catarrhal condition of the mucosa A sympathetico-mimetic drug causing constriction of the arterioles is used either in the form of a nasal spray or oily solution In practice 80 per cent ephedrine in liquid paraffin is found very satisfactory.

ii *Rest*.—There is nothing but masterly inactivity which will allow a damaged drum to return to normal, and the patient must not be permitted to fly until that has taken place In mild cases this amounts to two or three days, and in more severe cases up to fourteen days or more

iii. *Elimination of Septic Foci*.—Removal of chronically infected tonsils, nasal polypi, or other sources of nasopharyngeal infection is a necessary step in attempting to procure the proper functioning of the Eustachian tubes

iv *General Physical Condition*.—There is no doubt that this plays a large part both in prevention and cure of the condition, and in this respect ultra-violet light, adequate vitamin intake, healthy outdoor activities, and tonics all have their place

c. CHRONIC CASES.—Certain cases of recurrent otitic barotrauma caused by excess of lymphoid tissue around the pharyngeal end of the Eustachian tube can be greatly improved by irradiation with gamma or X rays.

## SUMMARY AND CONCLUSIONS

Otitic barotrauma was a frequent source of disability in operational aircrew in wartime, producing long periods of non-effectiveness It is an entirely preventable condition except in the [illegible]

[illegible]

inequalities of pressure


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## *CHAPTER XIX*

# AVIATION DEAFNESS

## GENERAL CONSIDERATIONS

ACUTE and chronic impairment of hearing may result from the effects of noise and vibration on the organ of Corti Sound energy released in modern aircraft is quantitatively high (*Fig 103*),

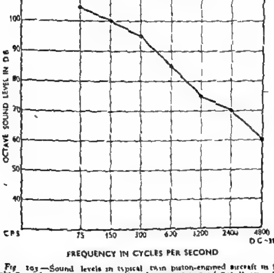



*Fig* 103 —Sound levels in typical twin piston-engined aircraft in flight Height 8000 ft, air-speed 180 m p h Airscrew tip-speed 740 ft sec (*After H Graebner, by courtesy of the 'Journal of Aviation Medicine'*)

but the frequencies of greatest intensity are at the low end of the acoustic spectrum, namely, *110 to 115* double vibrations per second. Conversational range lies between 300 and 3000 double vibrations per second. Although there are individual variations in susceptibility to acoustic trauma, it may be stated that single exposures result in acute auditory fatigue in the frequency zone of

approximately 4100 double vibrations per second The effect of repeated exposures tends to be cumulative, producing permanent alteration in the high-frequency area of the audiogram. Examples of audiograms of aircrew who have been exposed to varying degrees of acoustic bombardment are shown in *Figs.* 104–107. In acute and chronic cochlear fatigue there is an impairment in the ability to distinguish consonants through the intercommunication system,

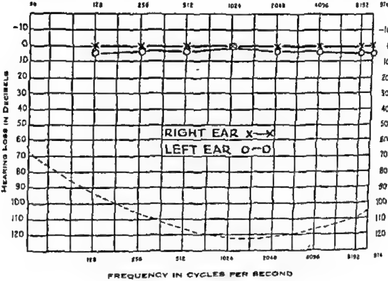



*Fig* 104 —Audiograms showing the effect of protecting the ears by wearing a helmet Pilot aged 25 Total flying hours 1620 Has always worn a helmet

*(Figs* 104–107 *from contributions to 'Aviation Otolaryngology', by E D D Dickson and others, by courtesy of Headley Bros)*

and in view of the importance of radio communication, the preservation of normal acuity of hearing for consonants is most desirable. Words such as sister and Chichester become indistinct in the early stages of high-tone deafness

## AETIOLOGY

The summation of all these vibrations is caused by the following individual factors :—

**1. Exogenous.—**

*a.* Airscrew tip-speed noise.

*b* Engine explosions, and expansion of exhaust gases.

*c* Slip-stream effects on the aircraft structure

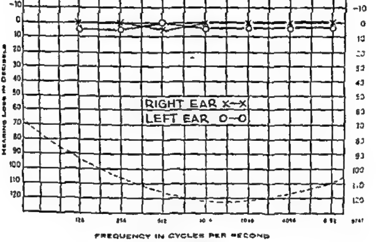



*Fig* 105 — Before flight

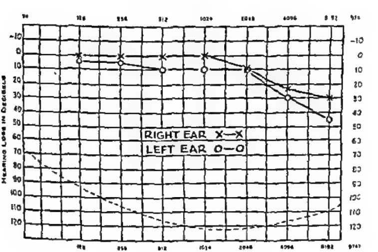
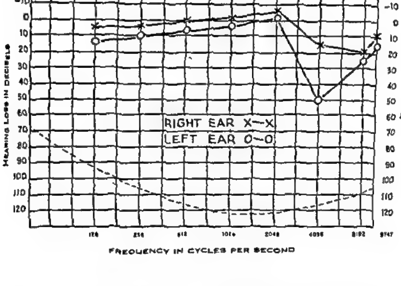



*Fig* 106 —Ten minutes after landing

*Figs* 105, 106 —*Audiograms of pilot aged 20 years taken before and after flight of one hour's duration in twin-engined bomber* Ears unprotected Left ear nearer engine Noise level, 119–123 phons (H.S.)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HEARING LOSS IN DECIBELS
FREQUENCY IN CYCLES PER SECOND
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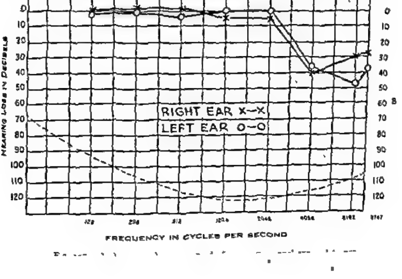
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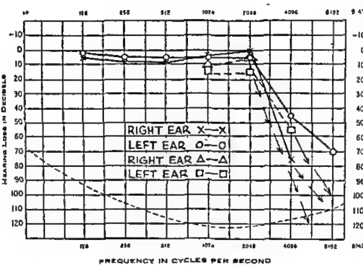


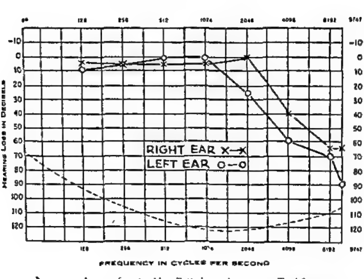


[illegible] Total flying, 100 [illegible] five years Has [illegible] ction lessened D [illegible] Total flying 2000 [illegible] Rinne positive [illegible]

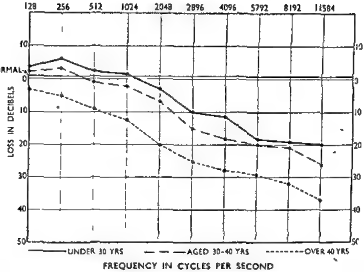


*Fig* 108 —Audiograms showing decrease in auditory acuity with age (*After H Graebner, by courtesy of the 'Journal of Aviation Medicine'*)

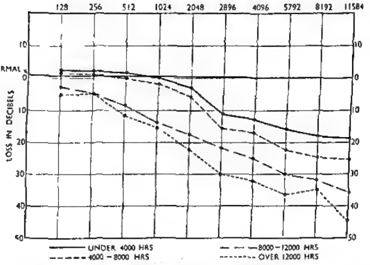


*Fig* 109 —Audiograms showing decrease in auditory acuity with increased flying hours. (*After H Graebner, by courtesy of the 'Journal of Aviation Medicine'*)

conclusively a causal relationship between frequency of bombardment, continuous flying activity, and decrease in auditory acuity, a fact which might well have an important bearing on compensation and occupational disability.

2 A series of audiometric investigations was also made by Senturia on 500 healthy males, between 18 and 27, who had not previously been subjected to aircraft noises In this experiment

*Table XXI* —AVERAGE DECIBEL HEARING LOSS—CHRONOLOGICAL AGE GROUPS

| 128 | 256 | 512 | 1024 | 2048 | 2896 | 4096 | 5792 | 8192 | 11584 |
|---|---|---|---|---|---|---|---|---|---|
| Average Age 26 3 Years (under 30 Years) 382 Ears Average 1742 Air Hours | | | | | | | | | |
| +5 5 | +6 8 | +3 0 | +1 9 | −3 6 | −10 2 | −11 5 | −18 0 | −18 5 | −20 5 |
| Average Age 33 2 Years (Aged 30–40 Years) 454 Ears Average 4745 Air Hours | | | | | | | | | |
| +2 | +2 8 | −0 1 | −2 4 | −6 9 | −14 6 | −16 3 | −20 | −22 4 | −26 5 |
| Average Age 44 4 Years (Over 40 Years) 62 Ears Average 11,956 Air Hours | | | | | | | | | |
| −2 9 | −5 5 | −0 0 | −11 9 | −20 9 | −25 9 | −27 6 | −30 2 | −32 6 | −37 7 |

it was found that there was a 4096 tonal drop in the ears in 20 to 30 per cent of cases (*Fig* 110A), a 4096 tonal drop followed by recovery and then a further loss in 15 to 20 per cent of cases (*Fig* 110B), and a progressive deterioration in the higher frequency scale in 18 to 25 per cent of cases (*Fig* 110C)

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## TREATMENT

There is no cure for the condition once established, and it is progressive Sufficient evidence has presented itself to justify

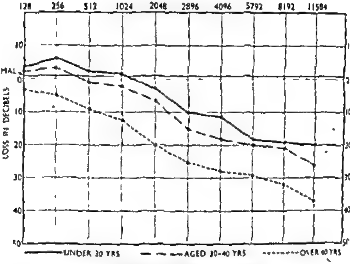


*Fig.* 108.—Audiograms showing decrease in auditory acuity with age. (*After H. Graebner, by courtesy of the 'Journal of Aviation Medicine'.*)

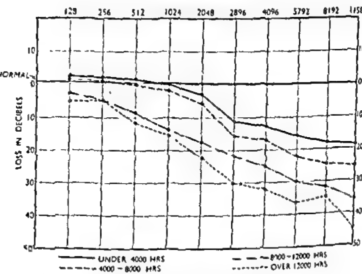


*Fig.* 109.—Audiograms showing decrease in auditory acuity with increased flying hours. (*After H. Graebner, by courtesy of the 'Journal of Aviation Medicine'.*)

conclusively a causal relationship between frequency of bombardment, continuous flying activity, and decrease in auditory acuity, a fact which might well have an important bearing on compensation and occupational disability

2 A series of audiometric investigations was also made by Senturia on 500 healthy males, between 18 and 27, who had not previously been subjected to aircraft noises In this experiment

*Table XXI* —AVERAGE DECIBEL HEARING LOSS—CHRONOLOGICAL AGE GROUPS

| 128 | 256 | 512 | 1024 | 2048 | 2896 | 4096 | 5792 | 8192 | 11584 |
|---|---|---|---|---|---|---|---|---|---|
| Average Age 26 3 Years (under 30 Years) 382 Ears Average 1742 Air Hours | | | | | | | | | |
| +5 5 | +6 8 | +3 0 | +1 9 | −3 6 | −10 2 | −11 5 | −18 0 | −18 5 | −20 5 |
| Average Age 33 2 Years (Aged 30–40 Years) 454 Ears Average 4745 Air Hours | | | | | | | | | |
| +2 | +2 8 | −0 1 | −2 4 | −6 9 | −14 6 | −16 3 | −20 | −22 4 | −20 5 |
| Average Age 44 4 Years (Over 40 Years) 62 Ears Average 11,956 Air Hours | | | | | | | | | |
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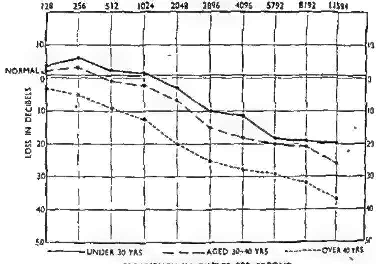
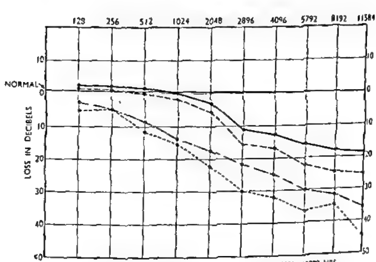



*Fig* 108.—Audiograms showing decrease in auditory acuity with age (*After H Graebner, by courtesy of the 'Journal of Aviation Medicine'*)

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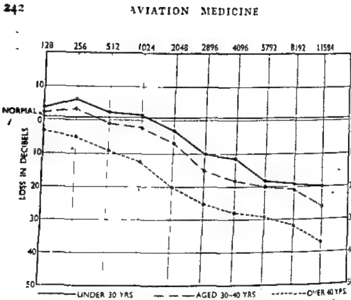
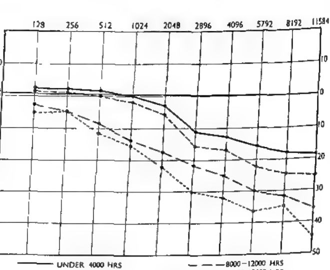



*Fig* 108 —Audiograms showing decrease in auditory acuity with age (*After H Graebner, by courtesy of the 'Journal of Aviation Medicine'*)

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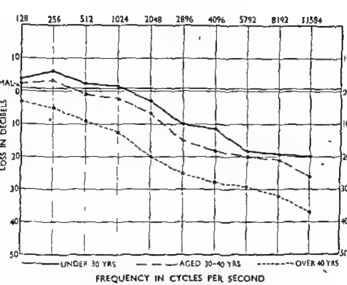


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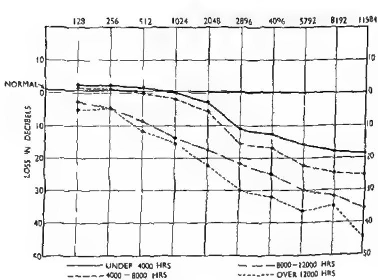


*Fig* 109.—Audiograms showing decrease in auditory acuity with increased flying hours (*After H Graebner, by courtesy of the 'Journal of Aviation Medicine'*)

*Table XXII*—TESTS OF EAR PROTECTION AGAINST NOISE

| | TYPE | PROTECTION (in decibels) |
|---|---|---|
| Plugs | A | 25 |
| Plugs | B | 25 |
| Plugs | C | 15 |
| Leather pad | D | 10 |
| High-altitude flying helmet fitted telephones as during use in Service Conditions | | 20 |
| Helmet and plugs | A | 35 |
| Helmet and plugs | B | 35 |
| Helmet and plugs | C | 30 |

(*After* F D D *Dickson*)

Type A was a plug with metal core inserted in a soft rubber casing, the latter attached to the metal in such a way as to enclose an air space between the materials

Type B was a wax plug covered by soft fabric, softened by contact with body temperature and therefore capable of being moulded to the shape of the individual ear

Type C was a tapering rubber tube closed at the outer end The material was somewhat harder and less flexible than that of Type A

Type D consisted of two specially designed soft leather pads, one for each ear, to be strapped on the head and fastened under the chin

series of tests that the standard R A F flying helmet, provided it is well fitting, is the best protection against noise (*see Fig* 104), but it is not easy to ensure that helmets are always worn on long flights or under tropical conditions, due to discomfort for the wearer Malleable plugs of wax or soft rubber are good noise barriers, but have hygienic disadvantages if used regularly, or in hot climates The older type of cup-shaped rubber ear-pad was found to be unsatisfactory by reason of the fact that the pads act as resonators on account of their shape Cotton-wool alone is an effective, although not absolute, noise barrier, and is frequently used by air-crew and passengers It appreciably reduces the noise levels entering the ear, is easy to apply, hygienic, and is unaffected by climatic conditions The control of noise and vibration in aircraft is the most important method of reducing troubles from this source and is the subject of a separate chapter (Chapter XII)

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every effort being made to lower the noise threshold of aircraft interiors as much as possible A maximum intensity of 70 to 80 decibels should be aimed at ; 50 to 60 decibels is the ideal.

Unfortunately the greater part of the noise produced in aircraft is the most difficult to eliminate, namely, airscrew tip-speed noise

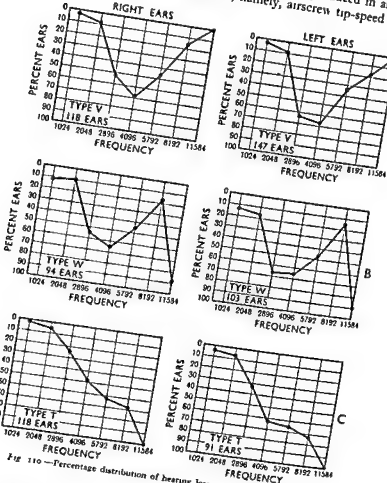


Fig 110 —Percentage distribution of hearing losses in aviation cadets (After H Graebner)

and exhaust noises, other factors contributing relatively little in this connexion. The advent of jet propulsion introduces further problems in this connexion, which are at present under review.

Better insulation of fuselages and protective ear coverings are valuable aids in this respect (*Table XXII*). Dickson has found in a

# CHAPTER XX

## SINUS BAROTRAUMA

### INTRODUCTION

This condition was a well-known source of disability in operational flying in the war, although not as common as otitic barotrauma It resulted in inevitable loss of flying hours for the patients, and did not appear to be related to any specific flying factor such as length of service, type of flying, position in aircraft, etc One striking factor noticed by some, but not all, observers, was the high incidence among personnel operating in a different climatic environment from that to which they were accustomed

### SYMPTOMATOLOGY

This is characterized by acute, often excruciating, pain over the affected area The onset is usually very sudden, occurring during descent from height, and is often likened to a sharp blow on the head, continuing in a severe and disabling form for hours, and occasionally days, without relief

### AETIOLOGY

This was at first obscure, but it was apparent that it was closely related to the incidence of otitic barotrauma and was primarily due to the imprisonment of air within a closed cavity Investigation by McGibbon and others has shown that the pain is probably caused by a submucosal hæmorrhage for which the following theory has been postulated On ascent to altitude, there is a relative ischæmia of the mucosa, and on subsequent descent there is an engorgement of the submucosa with associated œdema, effusion, and hæmorrhage In severe cases, this results in a stripping of the mucous membrane with the formation of a polyp-like growth Confirmation of this theory has been afforded by experiments on dogs, in which a similar condition has been produced in a pressure chamber by a complete blocking of the ducts of one sinus whereby this condition occurred, whereas in the contralateral sinus no abnormality was observed

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this respect Considerable help will be obtained by a knowledge of the patient, either by personal contact or by information obtained from his companions, and, finally and most conclusively, by his reactions in the pressure chamber In the case of a functional condition, the onset of the pain will not be accurately related to changes of pressure on descent but to what the patient thinks is happening, and this forms a helpful guide in elucidating doubtful cases A further point is that, on transillumination of the sinuses, functional cases are usually clear Microscopical sections of antral mucosa in true cases of sinus barotrauma show œdema, congestion, multiple submucous hæmorrhages, plasma cells, polymorphs, and lymphocytes, an identical picture with that found in chronic infective antritis

## CAUSES

No specific factors have been isolated as a cause of this condition except that of flying at height with an infection in the upper respiratory tract, with the superimposed factor of increased liability where any congenital, traumatic, or developmental abnormality of the respiratory system is present. An annoying feature, from the medical adviser's point of view, is that an undeniably large number of persons fly at height with a cold with no apparent ill effect This tends to bring advice given by a medical officer into disrepute

## TREATMENT

**1. Preventive.**—Aircrew should be instructed not to fly when any severe infection of the upper respiratory tract is present There is no doubt that enforcement of this principle greatly reduces the incidence of sinusitis and otitic barotrauma General measures aimed at maintaining a high standard of physical fitness by ultra-violet radiation, physical exercises, etc, also play their part

**2. Curative.**—

*a Immediate*—Re-ascent either in an aircraft or pressure chamber, followed by very slow descent, will usually ease the more acute pain, but in some cases sedative drugs will be found necessary at first

*b Subsequent*—Conventional methods of treatment such as radiant heat, vasoconstrictors, removal of any contributory factor together with a general improvement in the patient's physic[al] health, will usually clear up the condition Occasionally antr[al] drainage will be necessary, together with correction of any sept[al] deformity The period of disability varies from 48 hours to 10 days.

## DIAGNOSIS

This is made on the character and location of the pain and the circumstances in which it occurs. Radiological investigations show a thickening of the lining, and opacity of the affected sinus (*Fig.* 111).

*Fig* 111.—Radiograph of left frontal aerosinusitis, showing submucous hæmorrhage of lateral third of sinus (*From* '*Contributions to Aviation Otolaryngology*,' by E. D. D. Dickson and others, by courtesy of Headley Bros.)

## DIFFERENTIAL DIAGNOSIS

This sometimes presents difficulties, as the condition is one which lends itself very easily to imitation, and persistence of symptoms, in a person who does not want to fly. Several cases were at one time thought to be functional and great care must be exercised in

## CHAPTER XXI

# FATIGUE

## RECOGNITION

FATIGUE is a problem which permanently confronts a medical officer in charge of flying personnel, and his advice is constantly being sought by those responsible, concerning the ability of aircrew to carry on with their duties It is of paramount importance that a doctor should be able to recognize the condition, if possible before its onset, certainly at the very earliest stages. Furthermore, he should, by his knowledge of the person concerned, be able to form a shrewd estimate of the cause, whether it be excessive flying, inadequate rest, exposure to operational stress, the worry occasioned by domestic problems, the product of a complicated psychological basis, or a combination of all these factors Prompt recognition and correct treatment of fresh cases are among the most valuable assets that a medical officer in charge of aircrew can possess

## DEFINITION

Precise definition of fatigue is not easy, but it may be described as a progressive decline of a man's ability to perform his appointed tasks It may become apparent through deterioration in the quality of his work, lack of enthusiasm previously present, inaccuracy, lassitude, ennui, disinterestedness, a falling back in achievement compared with his fellows or compared with his previous output, or some other more indefinable symptoms Arbitrary divisions of the condition are not straight-forward, but for the purpose of simplicity it has been segregated, by those authorities qualified to judge, into the following headings

1 *Muscular Fatigue*—This occurs as a result of prolonged or intensified physical effort The treatment is simple, consisting of rest of the whole body or of the particular parts of the body which are fatigued by utilizing other muscle groups

2 *Mental Fatigue*—This is more difficult to recognize and occurs when a long period of heavy responsibility is undertaken The mental strain of repeated long-distance operational flights by

## SUMMARY AND CONCLUSIONS

Sinus barotrauma is a not infrequent cause of aircrew disability, although not as common as otitic barotrauma It lends itself as an escape mechanism for those who are unwilling to fly, and care must be exercised in establishing its diagnosis It can largely be prevented if adequate precautions are taken along the lines described.

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important feature is that this stage is probably first recognized by the person himself, who, if keen on his work, will make sincere efforts to overcome it and, failing that, in many cases will endeavour to hide it from his immediate superiors or medical officer. This state of affairs has led to a condition which may be described as delayed fatigue.

6 *Delayed Fatigue.*—A person's reserve of strength against fatigue may be likened to a reservoir which is constantly filling, and at certain intervals has a heavy drain upon it. It never runs quite dry because it is never quite emptied, and the supply being constant, replenishes it in time before further demands are made upon it. The day can be envisaged, however, when an extra strain is thrown on the resources, when they are not completely filled and the supply hitherto available becomes non-existent. Thus a keen operational person may be adding to his fatigue by long and trying flights. If he is in a position of responsibility he may not get quite as much sleep as the other aircrew members, but at the same time just enough for him to be restored sufficiently to carry on with his duties the next day. His reserve of nervous energy is steadily being reduced, however, until there is no margin. This is a very dangerous state of affairs.

If at this time, due to some operational necessity, a particularly heavy strain is thrown upon him, his reserve is inadequate to cope with the situation and serious consequences may result. More than one accident in which lives were lost on account of an error of judgement on the part of the pilot was due to an emergency of this type. The authorities had been warned that a pilot was operationally very near the end of his tether. The warnings were ignored but the wisdom of the suggestions was fully justified by the unfortunate result. The lesson to be learned is that, despite all outward appearances, adequate undisturbed and restful sleep (a minimum of eight hours), suitable recreation, and the avoidance of too many ancillary and administrative duties being thrust upon aircrew, must be strictly watched.

## AETIOLOGY

The causes are not easy to classify and there is no complete agreement concerning them, but all will agree that in varying degree they contribute materially to the onset of fatigue. Some of the causes enumerated obviously only apply to military flying, and can be discounted when considering civil operations.

**1. Psychological.**—

*a Fear.*—Fear is a potent factor in producing fatigue. Symonds postulates that it may result from excessive stimulation of this

night over heavily defended enemy territory, returning to base in bad weather, possibly with a damaged aircraft, is conducive to severe mental fatigue. In civil flying similar conditions of flight apply without the added military risks, but with such factors as changing weather conditions, meteorological hazards, and the added responsibility of carrying passengers.

It is surprising for how long a period of time a normal, healthy man can continue to work with no apparent diminution in the skill with which he executes his tasks A point can be observed, however, when fatigue sets in very rapidly. Errors of judgement on coming in to land are a frequent warning that such a state of mental fatigue is imminent. The process of landing is an intricate and complicated one, but well within the ability of the average, healthy, highly-trained operational pilot. If, however, there is present a degree of fatigue, there is a retardation of mental processes, and the essential rapid decisions and nervous reactions required are slowed down, with consequent increased liability to error

3 *Skill Fatigue*—This is a much more complicated type of fatigue and is usually more noticeable in those members of aircrew who have to perform accurate and complicated mental tasks, often under the difficult conditions which may be present in operational flying

4 *Acute Fatigue*—This has a definite muscular element The body becomes fatigued by postural strain, by hard work, or by the presence of unfavourable atmospheric conditions such as cold or anoxia The sensory apparatus becomes fatigued by hours of gazing at an instrument panel or searching the sky, the ear is constantly bombarded by the noises and vibration of the aircraft engines, by radio-communication signals, and by atmospherics and interference over the intercommunication system In addition to these factors emotional tension is frequently present.

5 *Chronic Fatigue*—This may occur at almost any stage in a person's operational career. It may be evident when an aircrew member of experience engages in a long period of operational duty without adequate spacing of duties or proper leave and rest periods Symptoms are not easily demonstrable, or simple to evaluate, unless the medical officer responsible for the diagnosis is well acquainted with his subject

An early sign is a very faint lack of zeal and interest. The subject's appetite may not be quite as good as hitherto, and he may begin to have fleeting occasions when he loses confidence in his ability. His reactions may become slower, and his judgement is neither as forthright nor as dependable as before. The most

fear is the predominant factor, and with the exception of a few extremely phlegmatic types of persons who appear to be totally unmoved by any set of circumstances, there is a mounting tension observable as an aircraft reaches enemy territory, and the first signs of opposition begin to appear. It is not until the enemy area is left behind once again that it is realized how great the tension was during the whole of that period There is a feeling of relaxation and relief of tension which has hitherto been absent.

The extra vigilance entailed over enemy territory is, in itself, a muscular effort The gunners are constantly scanning the sky for hostile fighters, the observer is making records of gun flashes from the ground, and the pilot is constantly beset by factors of fuel consumption, a heavy load, unfavourable minor technical shortcomings, and the whole burden of responsibility which the flight entails.

The violent evasive action which is necessary to avoid attacks by fighters, is a considerable muscular effort on the part of all concerned and may, furthermore, precipitate air-sickness which can be very exhausting Above all, the responsibility of carrying a bomb-load to a predestined target, within a few seconds of a pre-arranged time, under such conditions, produces an extreme state of mental tension

*d Casualties* —The sight of aircraft containing companions or friends exploding in mid-air, going down in flames, or descending crippled into hostile territory are all factors which influence the onset of fatigue Furthermore, the loss of one member of a closely-knit team, such as a gunner or navigator, has a very upsetting effect on aircrew, an effect which is often not noticed at the time. The man who can with equanimity see his friends killed does not exist, and rigid relegation of such matters into the background or deliberate suppression results in fertile ground for an anxiety state which can reach alarming proportions before it is checked Frank discussion, without overdwelling on the subject, is the healthiest and most satisfactory way of dealing with the matter

*e Purpose and Interest of Trip* —This is a surprisingly influential factor in the production of fatigue If a trip bears a special significance, and its accomplishment will have noticeable results, there is an air of expectancy on departure, and crews return relatively fresh and ready for more On the other hand oft-repeated trips are more productive of fatigue by reason of their very repetition, although heavy defences, and prolonged flight over fighter-protected areas, may play an over-riding part

*f Bad Weather* —Flying an aircraft in bad weather, and coming in to land under conditions of poor visibility, is a great physical

emotion in man without predisposition to neurosis, or lesser stimulus in the predisposed. An objective study and measurement of fatigue is very difficult, but Valentine has stated that there are certain minute trigger reactions which provide a constant behaviour response to certain stimuli, and from a knowledge of these, certain deductions can be made. Fear may exist quite independently of danger, and in operational flying it is a valuable asset, in that it stimulates the maximum physical and mental effort

The result of this is that whether there is an actual stimulation of fear on account of the presence of specific danger, or the latent fear mentioned above—the effect is fatiguing, and trained observers cannot fail to note the marked effect that it has on the onset of fatigue

*b. Formation Flying*.—The primary factor in formation flying is a constant state of vigilance and tension occasioned by the fact that, except for the leader, there is no independence, and the flying consists of maintaining a fixed position relative to another aircraft No two aircraft are exactly alike in performance; therefore, to fly in formation entails constant adjustment and readjustment of speed, height, and flying controls Formation flying is usually done by day and the allied Air Forces developed it to a particularly high degree in their daylight operations. In practice they found that very few pilots could keep accurate formation for more than a short time in this way, and so for day bombing, two pilots, turn and turn about, were employed All controls being duplicated, no movement within the aircraft was necessary.

Another factor in formation flying is reliance on another person Captains of aircraft become rather independent persons, by reason of the nature of their work, and while a crew may have implicit faith in the pilot it is quite remarkable how difficult a pilot finds it to fly exactly on a course, height, and speed predetermined by someone else in another aircraft, and the frequent minor criticisms which are either thought or spoken are evidence of the mental strain involved and represent a not inconsiderable factor in producing fatigue It was clearly demonstrated on return from daylight operational flights, that the leader of each formation was much fresher and less fatigued than his followers, and for this reason the position was one that was frequently changed.

*c. Enemy Opposition*.—Fatigue experienced by aircrew is greatly influenced by the amount of opposition encountered The opposition may be long, spread out and continuous, sporadic, or concentrated and intense over the target area, but the difference on return from a flight in which there has been little or no opposition is proof of this contention Fundamentally,

fear is the predominant factor, and with the exception of a few extremely phlegmatic types of persons who appear to be totally unmoved by any set of circumstances, there is a mounting tension observable as an aircraft reaches enemy territory, and the first signs of opposition begin to appear It is not until the enemy area is left behind once again that it is realized how great the tension was during the whole of that period. There is a feeling of relaxation and relief of tension which has hitherto been absent

The extra vigilance entailed over enemy territory is, in itself, a muscular effort The gunners are constantly scanning the sky for hostile fighters, the observer is making records of gun flashes from the ground, and the pilot is constantly beset by factors of fuel consumption, a heavy load, unfavourable minor technical shortcomings, and the whole burden of responsibility which the flight entails

The violent evasive action which is necessary to avoid attacks by fighters, is a considerable muscular effort on the part of all concerned and may, furthermore, precipitate air-sickness which can be very exhausting Above all, the responsibility of carrying a bomb-load to a predestined target, within a few seconds of a pre-arranged time, under such conditions, produces an extreme state of mental tension

*d Casualties* —The sight of aircraft containing companions or friends exploding in mid-air, going down in flames, or descending crippled into hostile territory are all factors which influence the onset of fatigue Furthermore, the loss of one member of a closely-knit team, such as a gunner or navigator, has a very upsetting effect on aircrew, an effect which is often not noticed at the time The man who can with equanimity see his friends killed does not exist, and rigid relegation of such matters into the background or deliberate suppression results in fertile ground for an anxiety state which can reach alarming proportions before it is checked Frank discussion, without overdwelling on the subject, is the healthiest and most satisfactory way of dealing with the matter

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and mental strain, and on many occasions a long trip has been successfully accomplished without any signs of fatigue, and at the end an approach and landing at an airfield has to be made under bad conditions The relatively short time during which this takes place, which may be anything from twenty minutes to two hours (due to waiting in turn for other aircraft to land), may produce more fatigue than the whole of the rest of the flight With increasing reliance on, and faith in, instrumental aids to navigational flying, this should diminish, but the methods employed are still not perfect, and the strain on the pilot under circumstances of this sort is still formidable. In addition to the fatigue outlined above, there is the purely physical factor encountered by flying an aircraft in turbulent weather, the necessary corrections required entailing considerable muscular effort.

*g Loneliness* —When an aircraft is on a solitary mission and is denied radio communication, or for some other reason is cut off from the outside world, an increased rate of onset of fatigue is noticeable. This is an observation which, although evident to a trained observer, is not easy to prove, but is probably closely bound up with the fear factor

*h Domestic* —Pre-occupation with domestic matters can be a contributory psychological factor in the production of fatigue. If a man is worried about his wife, family, or financial position, he will probably not sleep well or relax adequately in his spare time, and when on duty will tend not to be able to concentrate on the task in hand The onset of fatigue in such cases is more rapid and has more serious effects on the individual concerned than uncomplicated cases

**2. Physiological.—**

*a Anoxia* —Lowered partial pressure of alveolar oxygen is a predisposing factor in the onset of fatigue There is little experimental proof of this, and Barcroft has concluded that at present one cannot answer whether mental fatigue is due to oxygen want or not, although practical evidence points to the fact that it is so The impairment may be caused by the defect in any link in the oxidation process This is clearly demonstrable in cases where there is a minor degree of oxygen lack, such as is occasioned by a leaking mask or damaged tubes, but not enough to induce well-recognized symptoms of anoxia At the end of a flight where this has occurred, the person concerned will complain of excessive fatigue, unusual in him Furthermore, aircrew who consistently fly between 10,000 and 15,000 ft without oxygen are quite definite in their views that this is a tiring performance compared with carrying it out with an adequate oxygen supply. Emergency test

flights undertaken in a hurry with inadequate supervision of this point have yielded ample information which confirms this view.

*b. Carbohydrate Reserve.*—The metabolic cost of mental work is very slight, but in the considerable muscular effort entailed in flying occasioned by the execution of normal aircrew duties, plus the tension present during almost the whole of an operational flight, there is a definite lowering of blood-sugar content. In support of this contention there is nothing, apart from drugs, which appears to diminish fatigue more quickly than glucose by mouth. Many aircrew have their barley-sugar sweets which they use on long trips, and although the cause may be partly psychological, there is a definite lessening of the feeling of fatigue following the ingestion of glucose.

*c. Temperature Control.*—Fatigue is increased by inadequate temperature control, because at lowered temperatures there is a decrease in the general metabolic process in the body, and incomplete oxidation processes. Maintenance of correct body temperature, and prevention of wide fluctuations in the cabin temperature range, are important factors in preventing fatigue.

*d. Noise and Vibration.*—These are always present in an aircraft and so an assessment of relative noise is the only one that can be made. Desynchronization of engines or excessive vibration can be very tiring when continued over a long period. The human auditory mechanism is particularly sensitive to the vibration spectrum found in airscrew-driven aircraft which affects the auditory, visual, and tactile organs individually and collectively. The effects on special organs are discussed in subsequent sections. These studies have clearly shown the decrease in auditory acuity present in an ear which is constantly subjected to aircraft noises. In addition ocular imbalance has been demonstrated in affected subjects, usually a latent exophoria, and also an impairment of the knee-jerk.

From an objective point of view, the majority of aircrew cite noise and vibration very high on the list of fatigue-producing factors in flying, and a noticeable reduction in fatigue can be observed where special sound-proofing is employed in fuselage construction, or where engines are smoother or quieter than the average.

**3. Physical.**—

*a. Fitness.*—The physically fit subject will always, as in athletics, fatigue less easily than one who is not in the same condition, and for that reason physical training classes, outdoor games, and a high standard of physical fitness should always be encouraged in aircrew

The tonic effect of ultra-violet radiation exercises a beneficial effect, particularly in the winter months, although the effect is undoubtedly partly psychological.

*b Organic Disease*—Any form of organic disease, however slight, lowers a person's resistance to fatigue, the onset of which is noticeably quicker when disease is present

*c Rest in Flight.*—Inadequate rest in the air is a potent cause of fatigue, and methods for its prevention are discussed in the next section, it is a factor to which sufficient attention is not always paid by those who plan operations. Neglect in this respect will, in due course, lead to accidents due to error in a fatigued pilot or aircrew member

If adequate facilities for complete rest and relaxation in flight are not provided, there is a much greater liability of fatigue occurring than where proper arrangements are made Such arrangements need not be luxurious, but should consist of a bunk where the fully reclining position is possible and where the pilot, who has been sitting in a cramped position or straining his eyes, can allow himself a short period of complete rest. Such a factor can be of great importance in long flights, where the end of a journey may be a difficult approach and landing at a busy airport. In such cases, it is of great value to be fully refreshed by a short period of sound sleep, and the value of such a procedure can be out of all proportion to the time allowed or the trouble taken in providing such facilities

*d Rest on the Ground*—It is of great importance that when aircrew sleep at intermediate stops *en route* or at the end of a flight, all facilities for complete, undisturbed rest and relaxation under suitable conditions should be provided, and lack of such facilities can produce serious results if not rectified If, on retiring, the sleep of aircrew is disturbed by noise, unsatisfactory lighting, heating, or ventilation, or the movement of other occupants of the rooms, they will not obtain the necessary relaxation required.

*e Consecutive Flights*—The spacing of operations is of great importance, and close liaison between the medical officer and operational officer in this respect can, by prevention of onset of fatigue, raise the standards of performance considerably. Fatigue increases proportionately very rapidly when two flights are undertaken without an adequate interval for rest, and on a third flight under similar conditions fatigue is out of all proportion to actual time in the air It is uneconomical in personnel, aircraft, and accuracy of performance If there is not adequate time for complete rest between succeeding periods of strain, the results will be unsatisfactory and in some cases disastrous.

*f. Total Flying Hours*.—The laying down of precise rules as to flying hours is not practicable because there are so many variable factors involved, such as the type of aircraft, individual personalities, the nature of route, number of intermediate stops, climate, and general flying conditions. As a general rule in civilian flying a maximum of 125 hr. per month, and 1000 hr in twelve consecutive months have been shown in practice to be as much, but not more, than can be tolerated by the average aircrew member. These figures have now been largely agreed to on an international basis by a number of the larger air corporations, subject to overriding considerations on any particular route which by its nature demands special consideration, although some companies operate considerably longer hours without apparent ill effects.

*g. Duration of Flight Time*.—This is a very controversial subject over which much argument has frequently ranged, but it may be conceded in general terms that after flying approximately eleven hours fatigue begins to manifest itself in the average aircrew member. The effects on fatigue of individual flights are of course governed by a multiplicity of factors. These include the type of aircraft, its speed, the nature of the flight (those over the sea being noticeably smoother than those over land), and the number of intermediate stops. In addition there are such questions as to whether the flight is by day or night, whether a co-pilot is provided, and what provision is made for resting facilities *en route*. The fatigue experienced on a flight will also vary according to the flying qualities of the aircraft, the noise and vibration, the weather or other hazards, the number of landings effected, or the anxiety occasioned by a technical fault. The number of take-offs and landings is particularly important, involving as they do particular concentration, and the hazards associated with the environs of an airport. Thus a flight of a certain length in which a number of intermediate stops takes place, will be very much more productive of fatigue than one of identical length involving only one take-off and landing.

*h. Position in Aircraft*.—No place in a military aircraft occupied by crew members can be called really comfortable, but those aircrew members who are permitted most freedom of movement are the least likely to become fatigued. It has been postulated that the very fact of remaining in one position constitutes an important fatigue producing factor. The reaction of a vegetative nervous system to emotional stress in association with the appropriate endocrine responses, is, in the primitive state, accompanied by bodily activity. The inhibition of this activity, as experienced

in long operational flights, interferes with this biological response and may well have a cumulative fatigue effect.

*i Instrument Flying.*—Fatigue due to long periods of flying on instruments can be very marked, but is much more so in relatively inexperienced pilots. Just as to the uninitiated novice, driving a car is a constant strain, while a driver of experience thinks nothing of it, so the inexperienced pilot may be exhausted after a long flight on instruments, where the old hand will come back relatively fresh. In experienced pilots there is a great economy in observation, and the instrument panel is regarded as a whole, rather than attention being paid to individual dials and instruments.

## SIGNS AND SYMPTOMS

*a* **Inco-ordination.**—A feature of early fatigue is the lack of co-ordination in registering what is seen on the instrument panel. Normally speaking a pilot surveys the mass of dials as a composite whole and any unusual recordings are quickly noted. When fatigued they tend to coalesce into a distorted number of figures, and concentration on any one pair, or group, tends to magnify its importance out of all proportion to the whole. Thus over- or under-correction takes place. This in turn has itself to be corrected and a potentially dangerous state of affairs is engendered. This is particularly evident in bad weather when it is difficult enough, in any case, to keep an aircraft on the correct course, and constant adjustment of controls is necessary. Furthermore, other essential actions tend to be forgotten, when concentration is focused on one or another instrument. A skilled pilot, as in other spheres of technical knowledge, becomes fatigued much less readily than the novice, first, because, by reason of constant repetition, the whole flight is less of a strain upon him; secondly, because he is more readily able to recognize the symptoms of the onset of fatigue, and thirdly, because, when he recognizes them, he has his own methods of combating them and usually is able successfully to deal with them, largely due to an economy of effort expended in their execution.

*b* **Positional Awareness.**—Difficult as it is to note with accuracy the onset of fatigue, the factor which many regard as an early manifestation is an unusual awareness of bodily position and sensations. Normally speaking, we are relatively unaware of the position in which we are sitting and minor discomforts are tolerated without much thought. In military aircraft, particularly for the pilot, there is not the opportunity to change position very much, but in most cases, to a healthy person, a flight of eight hours or

more is accomplished without any discomfort other than a pleasant sense of relaxation and stretching which accompanies any change of position, such as getting out of the aircraft. When a pilot is in the early stages of fatigue, however, the minor sensations which arise from positions and movements of parts of the body begin to obtrude themselves upon his consciousness. He will begin to fidget, to adjust a strap, or move a buckle. Disproportionate attention will be paid to minor deviations from the normal bodily state, with consequent diversion of attention from the more important matters, such as instruments. At a further stage he is conscious of disabling cramps and sundry aches and pains, and an advanced condition of this sort may be the foundation of a definite neurosis about his physical condition. In a particularly sensitive, high-performance aircraft the sum of these sensations may yield somatic impressions out of all proportion to their relative value, resulting in unnecessary, and at times dangerous, alterations in the aircraft controls.

*c* **Lack of Judgement.**—A pilot's judgement begins to deteriorate when he is fatigued. He will either not notice slight variations in instrument readings or alternatively grossly exaggerate their significance. An example of this occurred in a fatigued pilot when a minor difference in oil pressure in one engine, which had actually been present the whole of the flight, was suddenly regarded by him as of such grave import that he switched off that engine, continuing on three only, and made an emergency landing away from his own airfield. In conversation informally at a later date, when he had had a period of rest, he admitted that his action was not governed by reason or experience.

Quick and vital decisions have to be made when coming into base in bad weather, when there are a number of other aircraft in the vicinity. On more than one occasion errors of judgement in experienced pilots have occurred which, on investigation, they themselves admit would never have been made had they been fresh and not tired.

*d* **Irritability.**—As fatigue increases a pilot becomes irritable and unreasonable. He may blame fellow members of his aircrew, the engines, the aircraft, the weather, or the ground crew in the control tower who may be bringing him into base. It is an unfailing sign that a man needs rest, which is recognized by aircrew no less than doctors, when a pilot starts blaming everyone but himself for conditions which are either non-existent, or are caused by his own shortcomings.

*e* **Flying Skill.**—In some pilots with experience, the onset of these symptoms is recognized by the subjects themselves. What

they often do not recognize, though apparent to the trained observer, is a progressive deterioration in flying ability. A polished pilot will do careless turns; coarse instead of fine movements of the controls, will be a few degrees off track instead of right on his course, will make a safe but gauche landing where hitherto he has executed flawless ones

*f* **Reaction Times.**—Reaction times are slowed, responses to stimuli are sluggish or absent, and the knee-jerk is impaired At first these changes are barely perceptible, but at a later stage replies on the intercommunication are delayed or hesitant, lack precision, and at times are noticeably in error.

*g* **Eye Movements.**—In the fatigued state a latent eso- or exophoria may become manifest and powers of convergence and fixation are reduced to a noticeable degree. In the cover test recovery may be delayed or absent.

*h* **Mental Aberration.**—This is a common sign of fatigue and is usually only evident in experienced pilots with a large number of operational flying hours Realizing that he is over-tired and having perhaps disguised the symptoms successfully, the experienced pilot will, by sheer will power, still execute the flying of the aircraft with skill and precision and will make no gross errors noticeable to an observer. He will, however, have varying degrees of mental aberration usually lasting only for a few seconds The period of recovery may, in the very skilled pilot, be well disguised, but in most cases is noticeable to his aircrew companions

*i* **Excretion of Keto-steroids.**—At one time a change in the quantity of keto-steroid excretion was thought to be diagnostic of the presence of fatigue, but experimental evidence on this point is not convincing, and the investigation involved is costly and intricate Recent work has confirmed the opinion that it is of limited value from a diagnostic point of view, and not entirely reliable or practical in application.

*j* **Weight.**—Some observers have noted a reduction in weight in fatigued aircrew, but there are so many other factors which come into the picture, that it is difficult to separate real from apparent causes. Thus, in a flight from England to the Far East such factors as climatic changes, enteritis, dysentery, changes in diet, extreme perspiration, and the influence of tropical conditions, may cause a reduction in weight which is normally regained after a short period in England, whereas on flights of equal length over temperate routes such as the North Atlantic, no such changes take place

Reid (1944), in investigations on bomber crews of the Royal Air Force, found that there was a significant loss in average weight

during the first third of an operational tour in Bomber Comma with no further weight loss as the tour continued, which loss cou not be related to other factors such as height or age He suggeste that this change was associated with operational stress (with which of course, fatigue is closely associated), and that during this same period there was a noticeable increase in relative liability to psychological disorders

## INCIDENCE

The incidence of fatigue among aircrew follows the order that might have been expected The pilot is the member who is most affected as would be expected by reason of his responsibilities, his muscular activities, and the general state of alertness, vigilance, and attention to duty required of him, allowing of no relaxation up to the time when the aircraft engines are finally stopped The advent of the automatic pilot, which will fly an aircraft on a predetermined course and height, has greatly assisted in this respect, but its uses are limited and it cannot be used at all times There is no doubt, however, that its use does lessen the incidence of fatigue amongst pilots

Piloting an aircraft is a physical and mental task The pilot must remain mentally alert throughout an operation, while the other members of the crew have periods when they can relax Gunners, for example, may be allowed considerable relaxation of vigilance over friendly territory, and the navigator's duties become less onerous when course is set for base Once the bomb aimer's task is done he can relax, but not so the pilot Every action he makes is governed by sensory impressions received a change in recording on the instrument panel, a slightly different note in one of the engines, erratic behaviour in the handling characteristics of the aircraft, bad weather or icing conditions, enemy activity, and, above all else, the fact that he is in charge of the aircraft and, as such, responsible for the efficient execution of its mission At the end of a gruelling flight, with all the attendant hazards and possible trouble, which have been enumerated above, he has the execution of the most formidable part of his task before him, that of landing the machine at base, possibly in darkness or bad weather Each sensory impression that he receives has to be noted, assessed at its true relative value, and dealt with by appropriate physical co-ordination, smoothly executed and accurately timed This is a relatively easy matter when the pilot is fresh, warm, and comfortable, but very much less so when he has been flying for hours and is cold and tired The other member

not have responsibilities as great as the pilot, and therefore with them the problem of fatigue is of less gravity.

Specialized forms of fatigue, however, manifest themselves in connexion with particular duties. Thus, prolonged listening to atmospherics and radio signals on the part of the radio operator results in auditory fatigue, as evidenced by diminished auditory acuity (*see* Chapter XIX). Similary, the navigator, by reason of the specialized nature of his duties, is liable to visual fatigue, and the steward, if called upon to perform arduous duties above 10,000 ft., unless supplied with a portable oxygen set, may well show considerable evidence of physical fatigue.

## TREATMENT

### PREVENTION

Prevention of the symptoms and effects mentioned above is largely along common-sense lines, but it cannot be too strongly emphasized that, in all cases, prevention is better than cure. The strain of operations is a severe one, and the more senior an officer becomes, the greater his responsibility, and, if he is a conscientious personality, the greater his self-reproach if his results are not up to standard. If he does achieve success, his probable reward is to be given more exacting tasks in the future. Such tasks make high demands on the physical and mental reserve of the person executing them, and it is essential that stringent methods are employed to maintain a high state of fitness in order, as far as possible, to prevent the onset of fatigue. Some of the more important factors in preventing its onset are as follows:—

**1. Sleep.**—A minimum of eight hours per night for all aircrew is essential. It is, furthermore, very important that the sleep should be undisturbed and for this reason it is desirable that aircrew be accommodated in a separate wing or building so that when they go to bed late after a flight they can sleep without noise or interference. Heating and ventilation of sleeping quarters is most important and every effort should be made to ensure that the rest is completely refreshing, relaxing, and undisturbed. Individual bedrooms should be provided for all aircrew members whenever possible, particularly pilots. Where sharing is absolutely necessary, as dictated by local conditions, it should only be allowed among members of the same crew, otherwise rest will be disturbed owing to different duty hours and flight schedules.

In tropical countries air conditioning should be provided; failing that, adequate ventilation, and in addition, insect proofing of all beds and sleeping quarters to ensure freedom from disturbance.

It is not always easy to sleep in great heat, or at unaccustomed times, and every endeavour must be made to encourage aircrew to get the maximum amount of refreshing and restful sleep. When flying schedules are arranged this important factor should not be forgotten.

2. **Off-duty Periods.**—Whenever possible crews should not be called upon to operate without adequate intervals for rest, except in cases of extreme operational necessity, and complete relaxation on these off-duty periods should be arranged. Personnel should be encouraged to get off the station and away from operational environment where possible.

3. **Leave Periods.**—These should be regular, frequent, and inviolate. A man should know when his leave is coming and that nothing will interfere with it. The importance of this factor in combating chronic fatigue cannot be over-estimated. Many persons have been helped over the last two or three operations by the knowledge that before long they would be enjoying a good holiday and rest. Every effort should be made to eliminate any psychological cause, as mentioned in a previous paragraph, by granting special leave to settle domestic matters, or endeavouring to assist aircrew in dealing with personal problems.

4. **Length of Period on Operational Duty.**—When deciding on the number of operations which aircrew can undertake either at a stretch or in sections, an individual must be carefully watched to see how he reacts to flying, and appropriate action taken where necessary. It is important that at the end of any agreed period of duty the rest is complete.

5. **Drugs.**—Many different drugs have been tried out with the object of preventing the onset of fatigue; the more important ones are as follows:—

*a. Caffeine.*—This has been a successful and widely used drug, and large numbers of aircrew are enthusiastic about its use in preventing the onset of fatigue. The recommended dosage is two 5-gr. tablets per ten-hour flight, to be used at the discretion of the person concerned. Although reports vary widely there is a sound majority of opinion in favour of its use.

*b. Benzedrine Sulphate.*—This, by reason of its powerful action, was used with caution at first, but in selected cases, provided there is an intelligent appreciation of its use and abuse, it is valuable, and has been used by experienced pilots with beneficial results. The optimum dose is 5 mg. taken immediately after take-off, or an hour before landing. Recent tests have shown equally effective results with dexedrine, without any of the unpleasant side-effects, but further reports are necessary before an authoritative statement can be made.

**6. Cockpit Lighting.**—This is discussed in detail in Chapter III (p. 58), but it must be emphasized here that there is adequate evidence to show that a well-designed and properly laid out cockpit and instrument panel as well as proper cockpit lighting are essential if fatigue is to be avoided (*Fig.* 112); glare and reflected light, or, alternatively, inadequately lighted instruments, can be a potent factor in inducing fatigue.

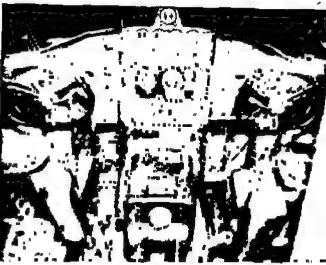


*Fig.* 112.—A typical modern four-engined airliner cockpit, showing duplication *of controls and blind-flying instruments for pilot and co-pilot.* (*By courtesy of "Flight."*)

**7. Provision of Resting Facilities on Aircraft.**—While it is admitted that the captain of an aircraft is never relieved of his ultimate responsibility in flight, there are occasions in a long flight when complete muscular relaxation is vitally important, and if sleep can be obtained mental relaxation is achieved as well. The benefit of a short period of rest thus acquired can be out of all proportion to the time actually taken, and may well provide a margin of safety which is invaluable at the end of a long and tiring flight. It is then that the maximum concentration, physical and mental, is required, and it may well be the time of greatest strain and hazard, due to weather or airport conditions. A short period of complete rest and relaxation at an earlier period in the flight may provide just that reserve of effort that is needed, and it is very striking what a difference even a few minutes' rest makes to a fatigued pilot, and how short a period is necessary to restore all the clear thinking essential for his tasks. Stress should be laid

on the fact that the completely recumbent position is essential for muscular and postural relaxation, the provision of a seat or chair which does not permit of this is not adequate for the purpose. If the flight is likely to exceed eleven hours, the question of providing slip-crews or co-pilots should be considered. On routes where these problems have been encountered there has been a noticeable increase in efficiency subsequent to such measures being instituted.

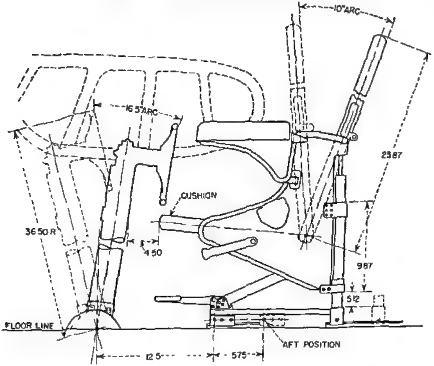
**9. Rest at Intermediate Stops.**—It is often forgotten that a frequent source of fatigue on long flights occurs at stops on the ground. The explanation of this apparent anomaly lies in the fact that once the preliminaries of a flight are attended to, routine flying can be comparatively unexacting for long periods. At intermediate stops, however, all sorts of indeterminate delays and uncertainties can be very unsettling and fatiguing. Thus a stop may be scheduled for one hour, just time for a meal, a flight plan, and refuelling. The weather report, however, may be unsatisfactory and a period of waiting ensues, which may or may not be restful for passengers, but is the very reverse for the responsible crew members, who have to make constant reference to the latest meteorological reports, and on whom the ultimate responsibility of departure lies. Alternatively the delay may be due to a troublesome engine or radio, and such worrying factors can be, and are, extremely tiring. The provision of adequate sleeping facilities is discussed in another paragraph.

**10. Food.**—Palatable food, well cooked and properly served at the right temperature, and at the correct physiological time, on the ground and in the air, is an important preventive of fatigue. This is discussed in detail in the chapter on DIET AND NUTRITION (Chapter V).

**11. Temperature, Ventilation, Humidity, and Oxygen Supply.**—The provision of an adequate circulation of fresh air and oxygen is important in preventing fatigue. This is clearly demonstrated in the difference shown by aircrew flying pressurized and non-pressurized aircraft. In the former, they arrive at their destination fresh and mentally alert. In the latter case, they are often fatigued and dull. The ideal temperature is 65–70° F. with a relative humidity of 50–60 per cent, with a circulation ensuring at least 1–2 lb. of air per aircrew member per minute. Oxygen should always be used in non-pressurized aircraft at heights greater than 10,000 ft. by day and 5,000 feet by night, despite the fact that at these heights its use has hitherto been decried.

**12. Seating Comfort.**—In the past adequate attention has not been paid to the question of seating comfort. The seating for the pilot and other aircrew members was designed to conform with

other cockpit requirements, and while this may have been adequate for short endurance flights of earlier aircraft, it is not so when the seat is to be occupied for long periods at a time. Seats should be designed on a basis of anatomical considerations, with plenty of adjustment for individual variations in build, and also variations which provide for different seating positions and muscular relaxation during flight, accessories should include armrests, headrests,




and different angles of pitch for the back of the chair (*Fig* 113) Attention should alto be paid to providing adequate support for the lumbar concavity

**13. Grouping of Instruments.**—This is very important and great strides have been made during the war in this respect If a pilot knows that the instruments are arranged in a certain way he can review them more swiftly and with much less mental effort Their correct distance from the eyes, not less than twenty-five

inches, is important if visual fatigue from constant accommodation is to be avoided. The comparison of the onset of fatigue with old and newly designed instrument panels is most encouraging.

**14. Noise and Vibration.**—Every effort should be made to reduce this to a minimum with insulating material, ear plugs, or other aids. Ear plugs of soft flexible rubber have proved effective in this respect, but have certain objections. Cotton-wool is an excellent alternative, and is in many ways more hygienic, especially under tropical conditions. This problem is discussed in detail in Chapter XII.

**15. Spacing of Operations.**—Adequate spacing of trips and operational tours is very important, and also very difficult to arrange when aircrews are far from home. A man does not want to take a prolonged rest time after time thousands of miles from his family, and careful arrangement of relief crews and operational duties will be necessary to achieve the rest and relaxation required between spells of duty.

**16. Psychological Factors.**—When adverse psychological conditions exist, it is well worth while, if operational circumstances permit, to release the person concerned for a short period to give him an opportunity of attempting to adjust matters. Frequently, however, a man is reticent in discussing such things and the true cause of the state of his health may not be recognized. In more serious cases, or where such a condition is allowed to develop, an anxiety neurosis may supervene and this may be a further influential factor in the production of fatigue.

## CURATIVE METHODS

There is only one cure for an established case of fatigue and that is complete, uninterrupted rest. The method of obtaining this will vary according to the severity of the case.

**1. Moderate Cases.**—Adequate rest should be fairly easy to obtain in the majority of healthy young adults. A mild narcotic such as nembutal gr. 3 nocte may be necessary, followed by two or three days of removal from flying. Nearly all cases respond well, and return to full flying duties.

**2. Severe Cases.**—There are certain cases, however, in which undisturbed sleep may not be obtainable because the subject is completely over-tired, his brain over-active, and the early stages of an anxiety state prevent the proper utilization of rest. In these cases a more drastic method is required, namely, continuous narcosis and psychotherapy. The aim of such treatment is to interrupt the vicious circle, or pre-occupation with the circumstances producing fatigue, and it has been used in selected cases

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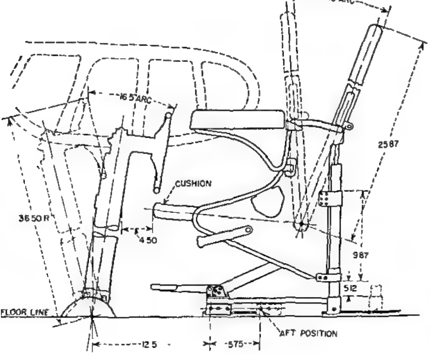


to control column

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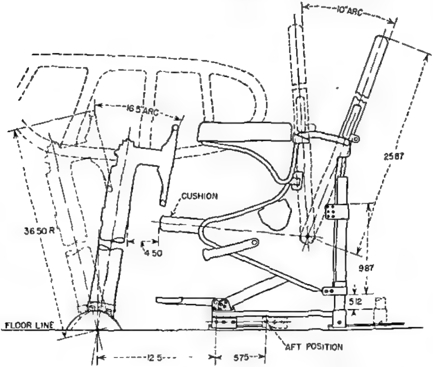


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duties It can be recognized in the early stages by a conscientious trained observer who is in the closest possible contact with the aircrew, both in the air and on the ground, but its objective measurement is difficult, and to date no satisfactory tests for fatigue have been devised, although some are undergoing experimental trial at the present time Prevention is very much better than cure, however, and if the problem is approached on the lines outlined above by persons skilled by practice at recognizing the symptoms, it can be dealt with in its early stages satisfactorily. Subsequent treatment in established cases, along the lines indicated, should result in a satisfactory outcome

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with considerable success *It is important* that an aircrew member suffering in this way should not be away from operations longer than necessary, because, to be successful, the treatment must be rapidly effective. The duration of the narcosis varies from seventy-two to ninety-six hours according to the severity of the case Briefly the method employed is as follows :—

A complete physical and psychiatric investigation is first made over a period of two or three days During this time nightly sedative doses of sodium amytal 0 2–0 4 gr. are given Any possible foci of infection must be eradicated as these are liable to flare up under treatment, giving rise to symptoms of systemic infection. Psychotherapy may be given during the waiting periods if deemed necessary.

Narcosis is then induced by the initial administration of 0 4–0 6 gr sodium amytal by mouth, the dosage increasing as the treatment continues; sound sleep for 20 hr. out of the 24 being aimed at for four complete days Repeated recordings of blood-pressure, pulse, and respiration rates should be kept, and for this reason skilled nursing is essential

Subsequently the patient is allowed to recover naturally from the narcosis, and for a few days nightly sedative doses of sodium amytal 0 4–0 6 gr may be given Graduated restorative physical activity is encouraged and full recovery is usually completed in one week.

Complications are uncommon and take the form of an undue deepening of the narcosis. The onset can be observed by a drop in the systolic blood-pressure below 80, and a dilatation of the pupils with a reversal of the light reflex. The administration of 100 per cent oxygen results in immediate recovery

The results of this form of treatment are most encouraging and it is claimed that a large percentage of people so treated *return to full operational duty.*

## SUMMARY AND CONCLUSIONS

Confirmation of the causes, mode of onset, and subjective and objective symptoms of fatigue have been demonstrated by putting aircrew in a mock-up of a cockpit, which was subjected for some hours to the movements and noises which would be found in normal flight A gradual onset of symptoms, very similar to those found in practical experience, were produced *in this manner, from which* a fair prediction of conditions likely to produce fatigue could be made

The question of fatigue is of primary importance in flying, and its early *recognition vital to the efficient performance* of aircrew

or area of complete absence of vision A migrainous type of scintillating positive scotoma with homonymous field defects then followed, frequently succeeded by headache, and often by nausea as well. These visual phenomena may occur during descent or after return to the ground Like oxygen want, the onset is insidious and the time unpredictable The history of clinical migraine, therefore, needs to be carefully evaluated in the preselection of candidates for a flying career Contemporary opinion emphasizes the similarity between the two syndromes, and the indications are that they both arise in the cerebral cortex from spasm of the cerebral arteries

(c) **Air Embolism.**—Other visual phenomena may be due not so

Ophthalmoscopic examination has not, as far as is known, revealed any abnormality in the fundi, either in these subjects or in those suffering from the migraine-like syndrome already described In view of the negative ophthalmoscopic findings, the progression of the scotomas from the centre to the periphery, and the sparing of the central vision, it is probable that both are manifestations of an ischæmia affecting the peripheral branches of the posterior cerebral artery In those predisposed to this form of cerebral irritation, the ischæmia spreads anteriorly and brings about the spasm of the cerebral vessels By the dispersal of gas bubbles in the tissues, muscular work or fits of coughing precipitate these symptoms, and although in pressurized aircraft both passengers and crew will be protected from changes of atmospheric pressure, engine failure or a leakage of the compressed air will bring about the symptoms of decompression sickness, of which the visual phenomena may prove the most embarrassing and alarming of all

## 2. VISUAL FATIGUE AND ARIBOFLAVINOSIS

**a. General.**—This problem received considerable attention in the early years of the war, but the results claimed are not confirmed by subsequent workers, who, among other researches, conducted investigations into the incidence of the condition in persons who had been prisoners of war in Japanese hands, and had consequently been deprived of essential vitamins for long periods Clinical signs were not demonstrable in such cases It is considered appropriate, however, *to record here the original observations* made The problem was confined to operations by day, when

*CHAPTER XXII*

# DISTURBANCES OF VISION ASSOCIATED WITH FLYING

UNDER this heading are discussed those visual disturbances associated with flying not described elsewhere in the text The effects of anoxia, alcohol, and acceleration on vision are included in the respective chapters on these subjects.

## 1. THE EFFECT OF LOW BAROMETRIC PRESSURE UPON THE VISUAL APPARATUS

(a) **Intra-ocular Hæmorrhages.**—In spite of adequate oxygenation of the tissues, a fall in the barometric pressure will provoke a compensatory *increase in the arterial and venous pressure through*out the body The strain upon the vessel walls is proportionate to the urgency of the demand induced by the rapidity of the barometric change This is more marked near the ground, so that rapid changes of height at low altitude may do greater damage to brittle and atheromatous vessels than corresponding changes in the higher regions Intra-ocular hæmorrhages affecting both vitreous and retina have been reported following enforced changes of altitude demanded by adverse weather conditions Commercial companies are of course fully aware of these implications, and regulate rates of climb and descent accordingly; doctors, however, should be able to advise elderly patients with signs and symptoms of arteriosclerosis of the possible effects of air travel, particularly on the long journeys to the Far East, where conditions often tend to prove fatiguing

(b) **Migraine.**—Visual disturbances associated with decompression sickness have been extensively investigated at altitude Engel and others found that in a series of 1361 exposures of 155 subjects to simulated altitudes of 30,000 to 38,000 ft, 17 subjects experienced migrainous scotomas 46 times *The incidence of* migraine-like headaches in subjects who were susceptible to this syndrome indicates a vascular predisposition The earliest manifestation, which was frequently overlooked, was a negative scotoma,

normal visual field. This prejudice no longer exists. At that time concern was also felt over possible damage to the pigment of the retina due to the effects of ultra-violet light at altitude, but such fears are not justified, because the glass or perspex as used in aircraft

A

B

Fig 114—A Circumcorneal and conjunctival injection in ariboflavinosis B Response to administration of riboflavin ($B_2$) in less than a week (*By courtesy of Messrs Parke, Davis and Company*)

cockpit windows provides adequate absorption of ultra-violet light, and when dark glasses are worn as well, the risk is negligible Care must be taken that the lenses are of good optical quality, and the glass should be optically ground and not blown, because in the

after long periods of flying over clouds, sea, or desert, personnel complained of the following symptoms in varying degrees of severity There was aching, strain, and tiredness of the eyes, burning sensations, and gritty feeling under the lids, accompanied by photophobia, lacrimation, and blepharospasm In addition there was decreased visual acuity, diplopia, inability to focus clearly, and the presentation of false images, accompanied by headaches, dizziness, and occasional tinnitus. The condition was gradual in onset and became progressively worse unless dealt with A number of pilots did not report it in the early stages because they accepted it as part of the inevitable accompaniment of flying long hours by day, and therefore many of the cases seen were in a relatively advanced stage.

**b. Aetiology.**—All cases occurred in those personnel who had experienced extensive or prolonged flights by day in bright sunlight, or over clouds, where the light was particularly intense and no opportunity offered for shade. The highly reflective surface of aluminium cowlings or perspex increased the glares and light entering the eyes, and intensified those adverse effects. In the early stages, when dark glasses were not worn, and no attempt was made to lessen the intensity of light entering the eye, the condition steadily progressed until treatment along the lines described was subsequently initiated

**c. Objective Symptoms.**—As a result of experiments originally conducted in Canada, it was established that persons suffering from a deficiency of riboflavin in the diet reported ocular symptoms similar to those described, and examination of these cases with the slit lamp revealed a state of vascularization of the cornea (*Fig* 114) with symptoms as described The explanation postulated as to the mechanism of this vascularization of the cornea in subjects deficient in riboflavin is that the supply of oxygen and the removal of carbon dioxide is normally the function of the arterial and venous blood in those tissues which have a blood-supply The cornea, however, has no blood-supply. In this tissue the exchange of oxygen and carbon dioxide is brought about by a chemical reaction, the chemical concerned being riboflavin or vitamin $B_2$. If the diet is deficient in this vitamin, blood-vessels enter the cornea to take over the function of the missing riboflavin In those cases in which examination was possible, a vascularization of the cornea was present in 75 per cent of cases

**d. Treatment.**—The obvious precaution of providing dark glasses was neglected at first because of a not unnatural prejudice that all aircrew had against anything which might interfere with the

i It should be decided whether the vascularization is a true budding of new blood-vessels, or merely the opening up and engorgement of existing vessels in the cornea, which can be caused by some form of irritation, such as injection of toxic substances into the eye, conjunctivitis, or trauma such as is caused by rubbing, or the presence of a foreign body

ii In a true corneal vascularization the new vessels will be seen in all areas around the periphery, whereas in traumatic cases they will probably be located in one area only

iii Vascularization may be brought about by deficiencies of other substances, such as vitamin A and tryptophane, or by chemical and other corneal irritants

iv Some investigators consider that in true cases of riboflavin deficiency the marginal corneal vascularization is accompanied by opacities in the substantia propria, and this view is supported by the rapidity with which these signs disappear with treatment by riboflavin

The above circumstances do not invalidate existing views on the condition, but rather indicate that further subdivision of the syndrome may be elicited on careful investigation It is evident that the trained ophthalmologist will attain more accurate statistical evidence of true signs of riboflavin deficiency, as enumerated above, than one not so skilled, and therefore actual figures in support of the prevalence of the condition should be subject to further scrutiny and revision as applicable The symptomatology and satisfactory results of treatment, as described above, however, leave no doubt as to the value of this form of therapy for the condition in a certain number of cases

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latter case optical inaccuracies will be encountered which will distort vision. Polarized glasses have been experimented with but were discarded because they could not be accurately controlled or adjusted Steps should be taken to ensure that the shape of the glass is such that it protects the eyes from light entering at the sides For this purpose oval, rather than round, lenses are to be preferred. In addition to the provision of glasses those surfaces of the aircraft upon which the pilot's gaze would normally rest should have a matt surface to diminish the glare of reflected light. Adequate blinds and shades should be provided in the cockpit to prevent the entry of excessive light Here again, anything which tends to interfere with all-round vision is deprecated by aircrew. These combined measures, by lessening the amount of light entering the eyes, greatly diminished the incidence of eye trouble experienced

When work on this subject was originally conducted on a large number of aircrew cases exhibiting these symptoms, striking results were obtained by treatment with riboflavin. The normal daily adult requirement of riboflavin is 2·5 to 3 mg It is, however, rapidly destroyed by light, and any individuals subjected to an increased amount of light entering the eye, as occurs in high-altitude daylight operations, would experience an increased destruction of riboflavin in the eye. Therefore, an increased intake is necessary to maintain normality. Experimental observations and practical application of this treatment confirmed this view The ingestion of 3 mg. riboflavin daily for three months in established cases overcame the disability, reduced the riboflavin deficiency, and, with other precautions described above, prevented further symptoms. There was a complete disappearance of the condition, and subjects noticed an early marked improvement in 95 per cent of all cases treated

**c. Conclusion and Comments.**—An adequate daily intake of riboflavin is necessary to counteract increased destruction which takes place when flying for long periods in bright light A minimum intake of 4 mg. daily should be aimed at, and there is adequate evidence to show that these requirements are satisfactorily met by a normal diet. When associated with devices for reducing the amount of light entering the eye, no symptoms of eye fatigue should manifest themselves If, however, such symptoms appear, the results of treatment with riboflavin are very satisfactory Recent work on this subject has revealed a difference of opinion as to what degree of corneal vascularization constitutes an indication of pathological change due to riboflavin deficiency. The following features must be borne in mind when investigating the problem

further comment. Secondly, liability to frost-bite is strictly proportional to the oxygen supply to the part concerned, and, provided this supply is adequate, the liability is greatly diminished and frost-bite is unlikely to occur. A feeling of numbness in the fingers or toes is frequently a premonitory warning of diminished oxygen supply. Thirdly, contact with metal or other surfaces transmitting cold directly to the skin is a fruitful source of trouble, and in the war rear-gunners were particularly prone to this through handling guns to deal with stoppages, turret movements, etc, many severe cases occurring in this way Lastly, the moisture content of clothing increases the liability to frost-bite. Although the water-vapour content of air decreases with lowered temperatures, as shown in *Fig.* 81 (p 155), there are other sources of moisture, of which the most common is perspiration It is very difficult to clothe aircrew so that they are warm at altitude and not sweating profusely at ground level

**Areas Affected.**—The areas mainly affected in order of frequency are ears and nose, cheeks, fingers, and toes The reason for the susceptibility of the ears and nose are mainly that they are the most exposed parts of the body and are difficult to cover Varying types of woollen Balaclava helmets can largely overcome this With regard to the cheeks, frost-bite frequently occurs where there is contact with any metal, such as studs or buckles, and can be overcome by proper insulation of these items with chamois leather A second frequent cause of frost-bite of areas of the cheeks is pressure points caused by badly fitting oxygen masks, which by reduction of the circulation lower the resistance of the area concerned, treatment consists of removal of the cause Fingers and toes may be constricted by improperly fitting clothing toes may remain immobile in flying boots for many hours.

**Prevention.**—All methods of prevention of frost-bite should aim at maintaining the body temperature at adequate levels, and this can be achieved in many different ways

*a Interior Temperatures*—Aircraft heating is described in Chapter XI While it is a relatively simple problem in civil aircraft, it is an extremely difficult one in military aircraft, therefore, much more attention has to be paid to heating supplied through clothing, rather than in the aircraft itself, but to assist this as far as possible interior heating by one of the standard methods should always be employed

*b Aircraft Oxygen Supply*—It has repeatedly been shown that any deficiency in the oxygen supply greatly increases the liability to frost-bite, and an adequate supply at all times, from the ground up, will go far to eliminate a basic cause of the trouble

## CHAPTER XXIII

# FROST-BITE

**The Problem.**—This problem ranked high in the causes of disability among aircrew in the early stages of the war, caused a loss of operational hours, and impaired flying efficiency (*see Table XI*, p 154) It became progressively less with the passage of time. It does not represent a serious problem in civil aviation At heights of over 20,000 ft temperatures are uniformly cold,

*Table XXIII*—ALTITUDE, PRESSURE, TEMPERATURE TABLE

| ALTITUDE | PRESSURE | TEMPERATURE |
|---|---|---|
| ft | mm Hg | deg C |
| 0 | 760 00 | 15 0 |
| 5,000 | 632 30 | 5 1 |
| 10,000 | 522 60 | − 4 8 |
| 15,000 | 428 80 | −14 7 |
| 20,000 | 349 10 | −24 6 |
| 25,000 | 281 90 | −34 5 |
| 30,000 | 225 60 | −44 4 |
| 35,000 | 178 70 | −54 3 |
| 40,000 | 140 70 | −55 0 |
| 45,000 | 110 80 | −55 0 |
| 50,000 | 87 30 | −55 0 |
| 55,000 | 67 76 | −55 0 |
| 60,000 | 54 15 | −55 0 |
| 65,000 | 42 65 | −55 0 |
| 70,000 | 33 59 | −55 0 |
| 75,000 | 26 45 | −55 0 |
| 80,000 | 20 83 | −55 0 |

irrespective of whether the aircraft is flying in tropical or other climates, and in the majority of war-time night operations in winter at heights of 20,000 ft or more the problem was an ever-present one It is not uncommon under such circumstances to experience temperatures ranging from −45° to −55° C Variations of temperature and pressure with altitude are shown in *Table XXIII*.

**Causes.**—The causative factors in the production of frost-bite in order of importance are as follows. First, the condition is dependent upon the temperature experienced, which needs no

set aside for the purpose, just prior to flight. A fruitful source of trouble is the habit of wearing flying boots on the ground and walking about in them, whereupon in the air the perspiration quickly freezes, and frost-bite is the result

*d. Circulation*—A well-functioning circulatory system means an adequate oxygen supply to the parts concerned, and therefore every effort should be made to prevent constrictive clothing or equipment which might restrict or interfere with an adequate blood-supply Very few cases of frost-bite occur where the peripheral circulation is satisfactory

*e Food and Drink*—Provision of hot drinks and hot food [illegible]

*f Alcohol*—This is only mentioned to be condemned and should be entirely forbidden Experiments in the cold chamber have demonstrated its harmful effects The ingestion of alcohol promotes an *entirely fallacious feeling* of warmth due to dilatation of the superficial capillaries, but in effect there is a greatly increased heat loss, and a person's ability to resist cold is considerably lowered by taking alcohol If, however, the external air conditions are such that heat loss does not occur, alcohol can have a beneficial effect, and therefore the provision of rum in tea for aircrews returning tired and cold from a flight should be encouraged, and undoubtedly has beneficial results

*g The Skin*—Two interesting observations are made and confirmed by a large number of cases First, the presence of any oil, grease, or cream on the skin, which for many years has been advocated as a *protection*, and was used in the early days of the war, was found to predispose to frost-bite The reason is that the moisture content of all greases increases the liability of freezing and offsets any protection that the grease may be supposed to afford Personnel who reluctantly gave up its use were subsequently convinced of the value of this order Secondly, the harm done to the face by shaving can be clearly demonstrated The act of shaving usually removes a fine superficial layer of the dermis, with its attendant protective properties, and personnel who do not shave prior to flight, thereby leaving on this protective layer, notice considerably increased protection

**Treatment.**—Trial and error in the treatment of a large number of cases of frost-bite has shown that the following are essential requisites for satisfactory treatment First, the part affected should be rested at such a level that venous congestion is avoided

*c* *Clothing.*—Stationary dry air is a very poor conductor of heat, and all clothing efficiently designed for warmth makes use of this fact Ideal protective clothing, therefore, should be windproof and internally of such a texture as will absorb moisture from the skin In addition it should be able to contain, in its interstices, as much air as possible, by the use of specially designed underclothes With regard to windproofing, a closely woven gabardine of the Everest type has proved most efficient, and is lighter than leather. Lamb's wool still remains the most satisfactory lining, while a very large cellular design for underclothes in which each section is approximately 2 in. square, is excellent for preserving the air in a static state, thereby retaining the warmth of the body Inserted into the intermediate layers of clothing in some cases are electrical pads connected in series, supplying heat to the following five main points —

i. An area approximately 10 by 4 in. in the lumbodorsal area
ii. The calves
iii The dorsum of the foot.
iv. The hands
v The area of the neck and shoulders

An intermediate layer of silk greatly increases the retentive power of the cellular underwear.

Ideally clothed aircrew, therefore, in practice should wear cellular underwear covered with a layer of silk; over this, normal service clothing, such as battle dress with, as an outer garment, a windproof jacket lined with lamb's wool with electrical inserts as described above. For the hands, a silk underlay covered with wool and an outside glove of leather are adequate; for the feet silk undersocks with an overlay of woollen ones, and large fitting boots lined with lamb's wool are required. In many healthy persons clad in this way it will be found that electric heating is quite unnecessary, even at temperatures of $-40°$ to $-50°$ C. Loose-fitting clothes, especially socks, gloves, and boots, are essential, as tightness anywhere impairs the circulation and predisposes to frost-bite.

Clothing should be absolutely dry The importance of this cannot be over-estimated, and will be a recurring source of trouble unless carefully watched *Moist clothing is a good conductor* and readily conducts heat away from the body, furthermore it freezes easily, becomes hard and painful, and produces pressure points, which by a reduction in the circulation become susceptible *to frost-bite* *The body is constantly giving out moisture*; hence the importance of wearing flying clothes only when flying; a great reduction in the incidence of frost-bite can be achieved by ensuring that aircrew only put on their clothes in a warm, dry room especially

## CHAPTER XXIV

# BURNS

## INTRODUCTION

THERE are probably few conditions which have undergone more profound changes in treatment in recent years than that of burns, and the fighting services yielded their full quota of cases for clinical observation and appraisal of tried methods It is a constant

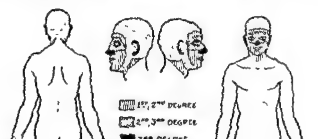


*Fig* 115—Diagram showing typical distribution of aviators' burns

(*Figs* 115–121, *Royal Air Force official illustrations Crown copyright reserved*)

problem in wartime operational flying, and an ever-present possibility in peace time where accidents are liable to occur in aircraft using highly inflammable fuels With the advent of jet engines using low inflammability fuels this danger is likely to be much less in the future Burns from aircraft are almost always severe, the

Secondly, asepsis should be obtained by protection of the affected part by loose bandaging, with plenty of cotton-wool. Thirdly, oxygen should be given continuously and has proved itself to be a factor of importance out of proportion to what was originally presumed The optimum supply is 8–10 litres per min for 1½ to 2 hours, followed by an interval of 1 hour, followed by a further 8 litres per min. for another 2 hours. Although the increase in carrying capacity of the blood is small, each c c carrying about 8 per cent more oxygen, the oxygen tension in the blood is raised so that the tissues with a damaged circulation receive a greater supply Massage and movement should be avoided at all costs as it results in further devitalization of the tissues. Many patients with frost-bite are suffer … from … arying degrees of shock, and the … warmth, rest, and hot fluids,

**Summary.**—Intelligent application of the methods described will reduce the problem to a negligible one, and towards the end of the war very few cases were experienced in operational flying

Protective measures are necessary in military aircraft, where escape from aircraft at high altitude may be necessary, or where there is a liability to prolonged exposure in cold conditions, but in civil flying the problem does not arise

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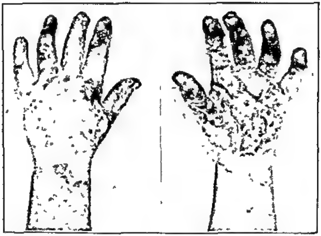

*Fig* 117—Severe burns of the hands Gloves not worn

*Fig* 118—Severe burns of wrist, seventh day The pilot wore gloves, but the space between sleeve and gloves was burned Gauntlets would have prevented this

type of conflagration ensuing from crashes or damage by enemy action producing intensely fierce heat, either from exploding bombs and ammunition or the burning of fuel. Except in those cases hopelessly burned beyond hope of recovery, the majority of burns are located on those areas of the body to which least protection is afforded, namely, the face and hands (*Figs* 115–121). The

*Fig* 116—Severe aviator's burns, eighth day. Note distribution on uncovered areas of face and hands (no gloves worn), and also knees, which were close to source of fire. Demarcation of the area covered by the helmet is clearly seen

next most frequently affected areas are the legs and abdomen respectively, and a constant campaign by responsible authorities to reiterate the vital importance of pilots and other aircrew keeping on their gloves, goggles, and headgear when landing, until all possibilities of an accident are over-ruled, is of great importance. Flash burns constitute a large percentage of all cases, and in many instances little or no effective first-aid treatment is instituted before they reach the hands of the medical officer

instituted The presence of other injuries complicates and alters the prognosis of any burn, and the intelligent application of simple first-aid measures such as rest, warmth, morphine, and antiseptic dressings greatly minimizes the severity and after-effects Operational hazards are another important factor, and a hazardous

Fig 120—Severe burns of head, third day No helmet worn

return flight with diminished oxygen supply, inadequate warmth, and the anxiety consequent upon returning in a damaged aircraft with wounded companions has an adverse effect on the prognosis, although extraordinary vitality is often shown by aircrew members under conditions of gravest adversity, which defy all the known laws of survival Many cases were witnessed in the war where a badly-burned pilot with a deficient oxygen supply, plus severe

## CONTRIBUTORY FACTORS

The classification of burns along the conventional lines, as used before the war, is not really of any value because there are so many extrinsic factors which alter and influence the primary essentials of

Fig. 119.—Moderately severe burns of face when helmet was worn

treatment or the ultimate prognosis, of which probably the most important is the period of time which has elapsed between the burn and the receipt of medical attention. In the case of a crash near an airfield it may well be only a short time, whereas in the event of incendiary bombs catching fire in the aircraft, or a crash in a remote area, it may be a matter of hours or days before treatment can be

## OBJECTIVES TO BE ATTAINED

The Royal Air Force has laid down the following objectives to be aimed at in the treatment of burns —

1 The control of primary infection by cleansing and the prevention of bacterial growth

2 The protection of the burned areas from secondary infection

3 The treatment of established infection

4 The dispersal of œdema, particularly of the hands, by elevation and movement.

5 The removal of all sloughs, which should be followed by epithelialization of the raw surface, either naturally or by skin-grafting, as early as possible The shortest periods in which this epithelialization can take place or be effected, are seven days in cases of partial skin loss, that is to say, slight burns, and eighteen days in cases of the loss of the full thickness of skin, that is to say, a severe burn

6 The avoidance of any further tissue damage as a result of treatment, and the anticipation and prevention of all avoidable deformities

7 The preservation of function in the underlying unburned structures throughout the treatment, for example, vision and joint movement This may involve surgical intervention

8 The physical and mental rehabilitation of the patient

9 The corrective surgery of inevitable deformities

The last five of these items constitute an advanced stage of surgical treatment and will not be dealt with here

## TREATMENT

**1. Slight Burns.**—As a first-aid measure a wet saline dressing is excellent It gives great comfort to the patient, which is important, it provides a barrier against subsequent infection, and is simple and easily applied by untrained personnel Subsequently an occlusive dressing of tannic acid or one of the aniline dyes is satisfactory if two provisos are observed —

*a* The wound is clean

*b* The area is relatively immobile

Many tragedies were caused in the early stages of the war when the tannic acid or dye treatment was in high favour and these remedies were injudiciously applied to the hands or other equally mobile areas, resulting in permanent contractures and deformities

Greasy dressings cannot be recommended, although their use has been popularly taught for many years They are no more effective than saline, much more uncomfortable and messy for the

lacerations from cannon-shell wounds, returned through intense enemy opposition on a long flight in a badly-damaged aircraft, and made an excellent landing, only to collapse immediately afterwards, gravely ill, a number of cases of this sort terminating in death

## CLASSIFICATION

Flemming states that for the purpose of convenience and clarification of treatment, burns may be classified as slight and severe

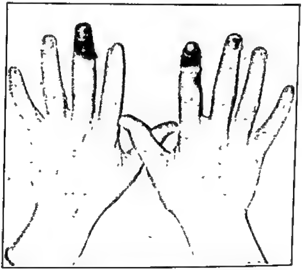

*Fig* 121 —Burns of tips of fingers in a pilot who wore gloves with holes at the tips of the fingers

1 *Slight burns* are those in which the patient exhibits no profound constitutional change, there is no discernible effect on function, and there are no features requiring urgent attention

2 *Severe burns* are those in which a profound constitutional disturbance is present, and in which the primary object is to deal with the patient's general condition, the secondary one the local treatment of the burn

Such a classification, though simple, is not always as straightforward as it sounds, as many cases of severe burns do not at first appearance fall into these categories, but careful observation, guided by experience in a number of cases, will usually result in an accurate estimate being made

*b Hæmoglobin Estimation*—It is almost useless to commence intravenous therapy unless steps are taken to estimate the hæmoglobin percentage at the outset and thus keep a check on what progress is being made Hæmoglobin estimation can be done simply and quickly and is an important and valuable guide at this stage of treatment. If the hæmoglobin is less than 75 per cent, immediate whole-blood transfusions should be considered, otherwise intravenous plasma is the choice

*c Intravenous Therapy*—No hard-and-fast rule can be laid down as to the amount to be given, or time taken in giving, and in actual practice it has been found that patients will take plasma as fast as it can conveniently be given A fluid intake and output chart should be kept from the beginning, and at a later stage the patient should have glucose-saline solution until his dehydration is overcome, and following that, fluids by mouth A minimum of time should be allowed before intravenous therapy is commenced Many lives have been lost through failure to institute this treatment properly and in time

*d Treatment of Burned Areas*—Under morphine the affected areas should be cleaned and the blisters snipped and dressed with tulle gras or vaselined gauze These dressings should, if possible, be put on with particular reference to comfort so that they can be left undisturbed for several days Splinting may be necessary at this stage in the case of fingers

*e Subsequent Treatment*—On return to bed, the barbiturates form the most useful hypnotic and in many cases are superior to morphine Sodium bromide has been found to give particularly restful sleep in these cases At a later stage (about a week) dressings will have to be removed and re-applied Pain, severe and distressing, is the inevitable accompaniment on these occasions, and a great measure of relief is afforded by utilizing saline baths for the removal of dressings, which float off with little or no discomfort From then on, daily baths are most comforting and appear to promote the healing process, but should not be continued once healthy granulations form, as a wet state of skin is not conducive to continued progress In the case of hands, irrigation by means of Stannard envelopes is very satisfactory

*f Protein*—There is a severe protein loss in all cases of burns and a surplus of this must be made available in the diet The easiest way to deal with this is by the inclusion of eggs in the diet, which are palatable and provide the protein required Even at this stage glucose is still of value in promoting the patient's general well-being It is important, as in all other bedridden states, to see that the patient's bowels are kept well open

patients, and tend to produce a clogged and unhealthy area of skin if left on too long. At a later stage of healing, however, they may well be applied for a short time. Penicillin powder and sulphonamide cream have been used locally with good effect, but a number of cases of sulphonamide sensitivity have led one to regard this with caution, and if asepsis is ensured at the beginning, this risk is unnecessary. Cases of slight burns of this sort can be treated as ambulant ones and usually make good progress.

The following is a soothing anæsthetic cream used in the Royal Air Force which gives relief as a first-aid measure. It has a melting-point of 115° F.

| | Per cent |
|---|---|
| Titanium dioxide (90 per cent) | 10 0 |
| Wool fat | 15 0 |
| Vaseline | 5 0 |
| Lanette wax | 10 0 |
| Glycerin | 25 0 |
| Manucol (4 per cent) | 35 0 |
| Chloro-cresol (0 1 per cent) as preservative | |

For the hands, oiled silk mittens containing sulphacetamide, which can easily be applied by untrained personnel, are invaluable. Cases of slight burns of this sort can be treated as ambulant ones and usually make good progress.

2. **Severe Burns.**—Any case of severe burns must be treated as a condition of extreme urgency and gravity, and too much stress cannot be laid on the false impression which may be given by a cheerful, intelligent, brave patient. Many a case has subsequently died owing to lack of appreciation of the gravity of the situation, even by a conscientious medical officer, deceived by the apparent fitness of the patient. The method suggested which has been evolved after trial and error is not without flaw and can doubtless be improved upon, but the actions outlined below in order of importance are the pre-requisites of successful treatment.

*a Treatment of Shock*—All severely burned patients, without exception, are badly shocked and anti-shock therapy must be instituted immediately they come under the medical officer's care. Morphine, radiant heat, rest, and comfort (*an important feature often neglected*) should receive first attention. It is very necessary that the rest and comfort be not disturbed until it is absolutely certain that the patient is making good progress. It is far more [illegible] th the attention

enthusiastic desire to get him to a burns centre. Many lives have been lost in this way, and no valuable feature of treatment is lost by delaying their transmission up to a certain limit

## CHAPTER XXV

# POSTURAL ŒDEMA

**1. Occurrence.**—This is a condition of relatively common occurrence in flying, the incidence of which varies according to the length of flight, the age of the passenger, and any deficiency in the cardiovascular system There is very little trouble on short flights of 2–4 hr and most cases are reported on long flights involving many hours or days

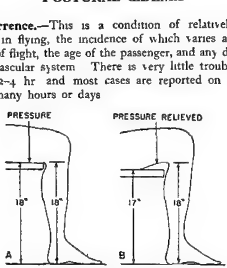


*Fig* 122—Diagram illustrating pressure exerted by front of seat on popliteal vessels (A) Pressure is relieved by lowering seat as in (B) (*After R McFarland*)

**2. Causes.**—Postural œdema is a condition in which the body fluids collect in the dependent parts of the body This is brought about by the following factors —

*a* Prolonged retention of the feet and ankles in the dependent position

*b* Pressure by angular edges of seats on the veins and lymphatic vessels at the back of the legs

*c* Absence during flight of muscular contractions in the muscles of the lower limbs present in walking or other forms of exercise

*d* The fine, high-frequency vibrations present in aircraft in flight

The above factors lead to a diminished return of fluids to the heart and a pooling of these fluids in the most dependent parts of the body such as the legs, feet, and ankles The condition is

*g Chlorides* —There may be hypochloræmia as a result of excessive exudation, and chlorides should be administered by mouth to counteract this

*h Skin-grafts* —Details of this are outside the scope of this book, and at this stage of recovery the patient should be handed over to the plastic surgeon.

## SUMMARY AND CONCLUSIONS

It cannot be stated too often that more patients have died as a result of zeal on the part of the medical officers in attempting to get them removed too quickly to burns centres rather than observe the procedures outlined above On the other hand, those cases that are in a fit state to be moved should be transferred to a burns centre as soon as possible, and first-aid treatment should be directed to that end. Transfer within seven hours of the accident is desirable, as after that time the effects of delayed shock will begin to manifest themselves, thus decreasing the chances of survival.

A progressive improvement in results and in the condition of patients admitted to burns centres has been observed as a result of gradual adoption of the methods outlined above, coupled with the lessons learned by trial and error.

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## CHAPTER XXVI

# TRANSPORT OF INVALIDS, INFANTS, AND PREGNANT WOMEN BY AIR, AND THE USE OF DRUGS IN FLYING

A VAST amount of experience was gained in the last war in the transport of casualties by air The organization for this vital part of the prosecution of the war, small at first, grew to a size which even the most optimistic person would not have foreseen in the early stages Transport aircraft were provided with skilled nursing orderlies and equipped with stretchers, oxygen equipment, and blood transfusion apparatus, and there is no doubt that many lives were saved, periods of ineffectiveness shortened, and complications reduced through being able to remove patients from the immediate operational area with a minimum of delay The question as to what cases were suitable for transport by air was largely governed by experience gained in the early stages, but it is true to say that at the end of the war there were practically no types of accident or illness which could not be dealt with in this way The problem was simplified, however, by the fact that the operations were usually conducted at 10,000 ft or less, and complications associated with height did not, therefore, arise, when considering the problem of transporting sick persons and invalids at heights greater than 10,000 ft further considerations apply The following paragraphs indicate recommendations which apply to those disabilities which are most commonly encountered in civilian air transport

## INVALIDS

### 1. Diseases of the Cardiovascular System.—

*a Uncompensated Cardiac Disease*—A passenger who has uncompensated cardiac disease caused by valvular disease of the heart or from hypertension would be well advised not to fly, because such a person is already suffering from anoxia, and the added load of the anoxia of altitude on an already impaired circulatory system may have harmful effects The nervous tension

aggravated in any passenger who has a weak heart, and is more common in persons over 50 years of age

**3. Remedial Action.**—Prevention is simple and consists of ensuring that the feet can be elevated to a height equal to that of the pelvis Return of blood and other body fluids to the heart is thus facilitated and the condition will not occur. Such conditions can *be assisted by the provision of seats in which pressure on the* popliteal area is avoided (*Fig* 122) and which can be adjusted to the fully reclining position with the feet elevated, or some form of leg rest which will achieve the same result as above Alternatively the provision of bunks will prevent the onset of the condition by allowing the passenger to rest in the fully recumbent position for periods during the flight

***4. Comparison with other Forms of Travel.***—*The* condition is not unknown in other forms of travel, but the incidence in these is very much less for the following reasons :—

*a* There are usually ample opportunities for walking about and using the muscles of the legs. The resultant contractions support the elasticity of the vessel walls and assist the return flow to the heart

*b* The fully *recumbent position is* usually possible from time to time

*c.* Long train journeys (12 or more hours) in the sitting position are not common

*d* The fine vibrations experienced in air travel are absent.

**5. Research.**—No detailed research is necessary in connexion with this problem, which is a straightforward condition with a clear-cut remedy It has been known for some years, but remedial action could not be taken in the war and immediate post-war years owing to the limitation of seating arrangements in aircraft

associated with flying may further aggravate the cardiac condition Patients with well-compensated valvular disease can, however, be accepted with caution, each case being considered on its merits If it is absolutely necessary for a person with uncompensated heart disease to fly, adequate oxygen should be available at all times

*b Hypertension*—Cases of hypertension should not be accepted if the systolic pressure is over 200 mm Hg or the diastolic pressure is over 100 mm Hg, but cases of mild uncomplicated hypertension can be accepted without risk

*c Coronary Heart Disease*—Any person who has coronary heart disease must be dealt with as an individual case, but it would be very unwise for a person to fly for a considerable period after myocardial infarction has occurred, on account of the increased demands made on the circulation at altitude. A person whose anginal attacks are easily induced and the patient who may have a marked apprehension of flying which aggravates his coronary disease should not travel by air. Any flight that necessitates going to a greater altitude than 10,000 ft is contra-indicated for a person with coronary disease. In general terms, the patient who has severe coronary disease should be advised not to fly unless other forms of transportation would put an even greater strain on the heart, if he does fly, oxygen should be administered whenever the altitude is more than 7000 ft, and a mild sedative should be prescribed to allay nervous tension

**2. Diseases of the Respiratory System.**—

*a Asthma*—Persons with asthma should not travel by air during an acute attack, and those suffering from frequent attacks should not fly The person with mild asthma may fly between attacks without discomfort

*b Tuberculosis*—The advisability of the patient with active pulmonary tuberculosis flying is debatable. Certainly if the lesion is more than minimal the patient should not fly. The most important factor in the question of whether a tuberculous patient should fly is the presence or absence of pneumothorax The dangers to a patient who has pneumothorax in travelling by air are numerous First, rapid contraction and expansion of the collapsed lung due to the changes in the atmospheric pressure are *deleterious to the healing process* Secondly, tearing of adhesions attached to diseased pulmonary tissue may result in hæmorrhage, or in the seeding of tubercle bacilli in the tissues around the cavity produced by the pneumothorax Thirdly, excessive compression of the lung may seriously reduce the vital capacity Fourthly, lowered atmospheric pressure may result in pericardial displacement.

The changes in the size of a pneumothorax in conditions of reduced atmospheric pressure are shown in *Fig* 123

*c Pneumonia, Bronchitis, Bronchiectasis, Pneumoconiosis, Pulmonary Abscess, Bronchogenic Carcinoma*—Patients suffering from pneumonia should be flown only when absolutely necessary When such patients are transported by air, they should be given oxygen, even though no evidence of respiratory impairment is

*Fig* 123—Radiographs showing pneumothorax at 1000 ft (A) and 10 000 ft (B) respectively

(*Figs* 123 124, *by courtesy of The Medical Director Mayo Clinic Rochester, U S A*)

present The reason for this is that pneumonia produces endogenous anoxic anoxia, and the addition of even a further slight anoxic anoxia, as a result of altitude, may be sufficient to cause the patient grave trouble

Bronchitis, bronchiectasis, pneumoconiosis, pulmonary abscess, and bronchogenic carcinoma are not in themselves contra-indications to a patient's flying as a passenger, unless such conditions are sufficiently severe to cause respiratory embarrassment

*d Upper Respiratory Infections*—The common cold, sore throat, and sinusitis, all increase susceptibility to aero-otitis and aerosinusitis, and the decision to fly under such conditions should be based on the severity of the infection The application of the usual vasoconstrictor drugs, such as amphetamine (benzedrine) or 2-aminoheptane sulphate (tuamine sulphate) may shrink the tissues in the nasopharynx and nasal cavity, so that the middle ear or accessory sinuses can be ventilated adequately

**3. Blood Diseases.—**

*a Anæmia*—Severe cases of anæmia and leukæmia should not be accepted on account of the greatly reduced oxygen-carrying

capacity of the blood The patient who has severe anæmia is already suffering from anæmic anoxia If that patient is taken to high altitude, anoxic anoxia is superimposed and clinical signs of anoxia may appear Thus the severely anæmic patient should receive oxygen when flying to prevent this complication The slightly anæmic patient can usually be transported by air without difficulty, because the anæmic anoxia is so small

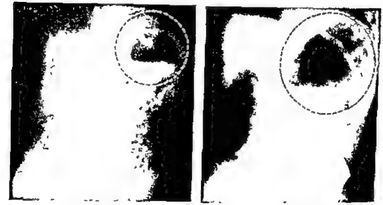


*Fig* 124—Radiographs showing expansion of intestinal gases under lowered conditions of atmospheric pressure A, Ground level, B, 40,000 ft

*b Other Blood Dyscrasias*—The advisability of transporting by air patients suffering from other blood dyscrasias is usually dependent on the severity of the associated anæmia and the presence of any cardiac or respiratory complications

**4. Surgical Conditions.**—

*a Acute Surgical Diseases*—Patients who have acute conditions for which operation is indicated should not be accepted in normal circumstances on passenger planes owing to the lack of adequate nursing facilities and also because of the risk of a crisis en route Such considerations, of course, would not apply to a patient who charters a private aircraft for his private use and arranges for skilled professional attention to accompany him, together with any special apparatus for oxygen supplies, blood transfusions, or other requirements

*b Convalescent Surgical Conditions in General*—Patients who are convalescent after operations stand air transport well, and can be carried, if no special attention or facilities are required

*c Abdominal Surgical Conditions*—Patients who have recently had abdominal laparotomy should not be accepted on account of the increase in volume of intestinal gases which occurs with lowered

atmospheric pressure Such a condition might result in the bursting of the sutures internally, or of those in the abdominal wall It should be remembered that in passenger-carrying aircraft, patients should not be accepted who might be objectionable to the other occupants of the aircraft, thus a colostomy over which a patient had perfect control in normal conditions might become uncontrollable at height, which condition, objectionable at all times, would be much more so in the confined atmosphere of a passenger cabin

**5. Diseases of the Gastro-intestinal System.—**

*a Peptic Ulcer*—A passenger who has peptic ulcer can be transported with minimal risk except when perforation is impending or has recently occurred When perforation seems likely and the patient must be transported by plane, he should be flown at a low altitude to obviate the danger of increased intragastric and intra-intestinal pressure due to the expansion of gases at increased altitudes (*Fig* 124) Cases which are chronic, and in which there is no history of perforation or acute exacerbation, should not suffer any ill effects from air travel

*b Diseases of the Gall-bladder*—Disease of the gall-bladder does not constitute a contra-indication to travel by air

**6. Diseases of the Central Nervous System**—There is no contra-indication to air travel in these cases except in the advanced stages, where special nursing is required or the patient might be objectionable to other passengers Thus a case of anterior poliomyelitis resulting in a paresis of arms or legs where an attendant was provided to help the patient could be accepted for air travel, but if there were any degrees of respiratory paralysis or incontinence, it could not The aerial transportation of patients who have sustained intracranial injuries or have recently undergone cranial surgery was accomplished by the armed services without adverse effect In order to combat the anoxia of brain tissue associated with increased intracranial pressure, oxygen should be administered during flight. Encephalography or ventriculography within the past seven days or any condition in which intracranial entrapment of air is demonstrated is a contra-indication to travel by air

**7. Diseases of the Endocrine System.—**

*a Disease of the Thyroid*—Moderate cases of hyperthyroidism and hypothyroidism are not adversely affected by air travel Advanced cases should not be accepted on account of the liability of cardiac involvement

*b Diabetes Mellitus*—Observations of passengers who have diabetes mellitus have revealed no serious effects from flying, but there are one or two points in such cases which deserve special

consideration First, *it should be ascertained that coexistent with* this disease there are no clinical signs of advanced cardiovascular degeneration which might in any way impair the circulation, thus *rendering the patient more susceptible to the effects of anoxia* Secondly, it is not always possible for diabetics to maintain the correct insulin-glucose ratio when travelling by air because of the *difficulty in regulating the diet*, and the timing of meals and insulin injections when the day's programme is dislocated by travel If these points are carefully watched, however, no difficulty should be experienced

**8. Mental Diseases.**—Mentally defective persons should not be carried on account of the possible danger to themselves and other persons in the aircraft It should be remembered that psychoneurotic patients are more liable to suffer from air sickness than normal passengers

**9. Infectious Diseases.**—These cannot be carried for obvious reasons

The medical authorities of the principal civil air corporations in Great Britain have recently published (in tabular form for easy reference) agreed recommendations for the guidance of medical practitioners who may be required to advise in such matters These are given on pp 302–305.

## PREGNANT WOMEN

Pregnancy is not an illness but a normal physiological state, and in the majority of cases may be expected to conform to average living conditions whether on the ground, at sea, or in the air. There is less risk of complications due to pregnancy in the later months than in the early stages, and there is no greater risk of mishap in air travel in such cases than any public carrier should be prepared to undertake. There is probably less risk than in a large proportion of road travel to-day. Theoretically, therefore, it should be possible to transport women by air in any stage of pregnancy up to the time of delivery In practice this has to be modified on account of the uncertainty as to the exact date of expected delivery, and the complications which may ensue as a result of a woman going into labour where no medical facilities are available and where the nearest medical attention may be many miles away Not only does this raise the question of risk to the patient herself, and inconvenience to other passengers, but it adds greatly to the worries of the captain of an aircraft, whose task is already a very responsible one. In such a case he may be called upon to face the question as to whether to return the aircraft to base, to land at some unsuitable airfield, or proceed on his

way, knowing that he is courting the risk of possible grave danger to one of his passengers  A good working rule which covers most of the requirements met with in passenger transport and at the same time avoids the element of risk mentioned above is to accept for air transport pregnant women in good health up to, and including, the eighth month of pregnancy

## INFANTS

to be less than that of adults  It is important to note, however, that once the symptoms of anoxia are observed, the subsequent decline is more rapid than in adults and they will succumb quickly unless remedial measures are taken forthwith

Pain due to failure of the Eustachian tubes to open during descent can be obviated by feeding the child during this period, the act of swallowing opening the tubes, alternatively, if the child feels pain it will cry, which action will produce the same result

## THE USE OF DRUGS IN FLYING

**1. Sulphonamides.**—The effect of high altitude on the action of certain commonly used drugs has been questioned  At high altitudes the action of drugs may be affected by changes in barometric pressure and extreme cold  The latter is not of great importance in modern commercial aircraft because of adequate heating facilities

The use of sulphonamide drugs at high altitude has been looked upon with suspicion because of the cyanosis which is seen occasionally even at sea level or low altitudes when sulphanilamide is used  This cyanosis is due to sulphhæmoglobinæmia and methæmoglobinæmia. Sulphhæmoglobinæmia and methæmoglobinæmia reduce the tolerance for altitude, or more correctly, the anoxia tolerance  However, as this complication is not frequently seen after administration of sulphanilamide, and as other sulphonamide compounds which do not produce this phenomenon are now used more commonly, the danger of such an effect is small  The use of other sulphonamide compounds now in common use, sulphathiazole and sulphadiazine, are not contra-indicated for passengers transported by air, except for the possible gastro-intestinal upset from the drug which may be aggravated by motion sickness

**2. Quinine Compounds.**—The toxic effects of quinine, such as visual and auditory disturbances, and the irritating effects of quinacrine hydrochloride (atebrine) on the gastro-intestinal tract have

MEDICAL CONTRA-INDICATIONS TO AIR TRAVEL

| CONDITION | LIMITING FACTORS | ESSENTIAL FACILITIES AND PRECAUTIONS IN FLIGHT | WHETHER ADVISABLE TO TRAVEL BY AIR |
|---|---|---|---|
| **1. Blood and Lymphatic System Diseases** | | | |
| i Anæmias | Less than 3,000,000 R B C per c mm , less than 50 per cent Hb (May need transfusion before flight) | Maximum altitude 5000 ft Oxygen must be available | Inadvisable unless aircraft is pressurized to 5000 ft |
| ii Leukæmias | Less than 3,000,000 R B C per c mm , less than 50 per cent Hb Gross enlargement of spleen Hæmorrhages (May need X-ray therapy before flight, which should not be within 4 weeks of the X rays) | *Maximum altitude 5000 ft* Oxygen must be available | *Acute cases should* be rejected, unless Hb is raised to 80 per cent by a blood transfusion Chronic cases inadvisable unless aircraft is pressurized to 5000 ft |
| iii Lymphadenoma | Enlargement *of mediastinal lymph-glands* revealed by X-ray film Fever of the Pel-Ebstein type | *Oxygen must be available* | Cases to be considered on their merits |
| **2 Cardiovascular Diseases** | | | |
| i Angina pectoris | Frequent or recent attacks Electrocardio*gram to exclude coronary occlusion* | Maximum altitude 5000 ft Oxygen must be available Movement in aircraft should be limited to minimum | Inadvisable unless in aircraft pressurized to 5000 ft , and attacks provoked only by brisk walk of *about ¼ mile* |
| ii Coronary occlusion | Symptoms within 12 months | Maximum altitude 5000 ft Oxygen must be available Movement in aircraft should be limited to minimum | Inadvisable unless in aircraft pressurized to 5000 ft |
| iii Valvular lesions . *a* Compensated | Degree of anæmia | Maximum altitude 8500 ft Oxygen must be available | If flight is under 8500 ft |
| *b* Uncompensated | Signs of *congestive failure* | — | Reject |
| *c* Congenital | Evidence of veno-arterial shunt (cyanosis), heart block, or severe hypertension | Maximum altitude 8500 ft Oxygen must be available | If flight is under 8500 ft |
| iv Myocardial lesions | Active disease or bradycardia In post-diphtheria cases 6 months must have elapsed since illness | Maximum altitude 5000 ft Oxygen must be available | Cases to be considered on their merits |
| v High blood-pressure | B P 200/120 mm Hg or above Headaches or loss of weight Pulsus alternans Cardiac asthma Unsatisfactory condition of optic fundus Albuminuria more than 2 per cent Cellular casts in urine | Maximum altitude 8500 ft Oxygen must be available | Inadvisable except in pressurized *aircraft* |

MEDICAL CONTRA-INDICATIONS TO AIR TRAVEL—*continued*

| CONDITION | LIMITING FACTORS | ESSENTIAL FACILITIES AND PRECAUTIONS IN FLIGHT | WHETHER ADVISABLE TO TRAVEL BY AIR |
|---|---|---|---|
| 3 **Diabetes** | Other than moderate types without cardiovascular disease which must be stabilized by diet or insulin Should have a recent blood-sugar estimation and report Fasting blood-sugar level should be *below* 250 mg per 100 ml | Must adhere strictly to prescribed hours of meals and insulin injections Not to move about at altitude more than necessary Oxygen *must* be available Hyoscine to prevent air-sickness | Only milder and moderate cases acceptable—that is, those not needing more than 50 units of insulin a day |
| 4 **Elderly** | Unsatisfactory cardiovascular condition In the case of a patient over 65 who is undertaking a long flight, it is advisable that a medical examination be carried out *to eliminate* anæmia or cardiovascular conditions An electrocardiogram may be necessary where doubts exist | Not to move about at altitude more than is necessary Oxygen should be available in non-pressurized aircraft | Depends on physical condition Pressurized aircraft advisable (maximum altitude 8500 ft ) for the very elderly |
| 5 **Gastro-intestinal Diseases** | | | |
| i *Peptic ulcer* | | | |
| *a* Quiescent and old perforation | As proved by absence of (i) Symptoms of activity (ii) Occult blood in fæces, (iii) X-ray evidence of active disease (iv) Proneness to travel-sickness | Not over 8500 ft Hyoscine to prevent air-sickness Carminatives for flatulence | Preferably by *pressurized aircraft* (8500 ft ) |
| *b* Active | Pain Occult blood in fæces X-ray evidence Proneness to travel sickness | Not over 5000 ft Limit movements *in aircraft* Hyoscine to prevent air sickness Carminatives for flatulence Follow dietetic advice | Normally reject Pressurized aircraft if journey essential |
| ii Post-operation | | | |
| *a* Appendicectomy | At least 10 days must have elapsed since the operation | Not over 8500 ft shortly after operation Hyoscine to prevent air-sickness | Flight should be under 8500 ft |
| *b* Herniotomy | At least 10 days must have elapsed since the operation | Not over 8500 ft shortly after operation Hyoscine to prevent air sickness | Flight should be under 8500 ft |
| *c* Other resections and *wounds* | Depends on condition of gut, fluid in abdomen etc Unable to go to lavatory unaided | Not over 5000 ft | Inadvisable except at 5000 ft maximum in pressurized aircraft |
| *d* Colostomy | Effect on fellow-travellers | — | Reject |
| iii Hæmatemesis and melæna | — | — | Reject |

MEDICAL CONTRA-INDICATIONS TO AIR TRAVEL—*continued*

| CONDITION | LIMITING FACTORS | ESSENTIAL FACILITIES AND PRECAUTIONS IN FLIGHT | WHETHER ADVISABLE TO TRAVEL BY AIR |
|---|---|---|---|
| **6 Genito-urinary Diseases** | | | |
| i Calculus | If attacks of renal colic are frequent | Hyoscine to prevent air-sickness | Normally acceptable |
| ii Nephritis | Systolic blood-pressure over 200 mm Hg Degree of anæmia (*see* Anæmia) Ascites or hydrothorax Unsatisfactory condition of optic fundi Albuminuria more than 2 per cent Cellular casts in urine Blood-urea more than 60 mg per 100 ml | Maximum altitude 8500 ft Oxygen should be available | Normally acceptable, but consider each case on its merits |
| iii Venereal | Must be free of active lesions, especially those of skin or buccal infections | — | Reject till non-infectious |
| **7 Infectious Diseases** | While infectious | — | Reject |
| **8 Liver Diseases** | | | |
| i Abscess | Those liable to burst | Maximum altitude 8500 ft Oxygen must be available | Normally reject If essential, travel below 8500 ft |
| ii Cirrhosis | Evidence of congestive failure Hæmorrhages Ascites or hydrothorax | Maximum altitude 8500 ft Oxygen must be available | Normally reject |
| **9 Mental and Nervous Conditions** | | | |
| i Brain tumours | Pressure symptoms Incontinence | Maximum altitude 5000 ft Doctor or nurse in attendance | Normally reject |
| ii Epilepsy | Frequently occurring fits | Attendant advisable Suitable sedative No alcohol | Inadvisable except in milder cases |
| iii Mental disease | Non-quiescent state Lack of control of bowel and bladder Homicidal or suicidal tendencies | Attendant essential Calmed with suitable sedative | Normally reject |
| iv Poliomyelitis | Not less than one month after onset (i e, must be non-infectious) Unable to walk to lavatory Respiratory involvement during illness | Attendant, if patient is not freely mobile Oxygen must be available | Acceptable |
| v Other palsies | Lack of control of bowel and bladder Unable to walk to lavatory | Attendant, if patient is not freely mobile Oxygen must be available | Decide each case on its merits |
| **10. Pregnancy** | Must not be beyond 8th month of pregnancy Evidence or history of repeated or threatened abortion, eclampsia, or travel sickness | Ensure that retention belt is round pelvis, not abdomen, at take-off and landing Sit in backward-facing seat, if available Oxygen must be available Hyoscine to prevent air-sickness | If medical certificate is satisfactory and weather conditions are favourable for smooth flight at altitudes under 9000 ft Oxygen available Pressurized aircraft advisable |

MEDICAL CONTRA-INDICATIONS TO AIR TRAVEL—*continued*

| CONDITION | LIMITING FACTORS | ESSENTIAL FACILITIES AND PRECAUTIONS IN FLIGHT | WHETHER ADVISABLE TO TRAVEL BY AIR |
|---|---|---|---|
| 11 **Respiratory Diseases** i Asthma | Severe attacks *Cardiac or renal* basis | Maximum altitude 5000 ft Oxygen must be *available* *Move* about as little as possible | Consider each case on its merits |
| ii *Emphysema and bronchitic conditions* | Dyspnoea Cardiac lesion *Offensive sputum* | Maximum altitude 5000 ft Oxygen must be available Move about as little as possible | Normally reject Consider each case *on its merits* |
| iii Fibrosis of lungs | *Extensive* | Maximum altitude 5000 ft Oxygen must be *available* *Move* about as little as possible | Normally reject If essential travel in aircraft pressurized at 5000 ft |
| iv *Lobectomy* and pneumonectomy | Must be more than 3 months since operation Breathlessness on moderate *exertion* | Maximum altitude 5000 ft Oxygen *must* be available Move about as little as possible | Normally reject If essential travel in aircraft pressurized at 5000 ft |
| v Pleurisy *a* Dry | *Pain* and *extent of lesion* Fever | Maximum altitude 5000 ft Oxygen must be *available* *Move* about as little as possible | Normally reject If essential travel in aircraft pressurized at 5000 ft |
| *b* Wet | If one side of chest is more than half filled (Tap if necessary) | Maximum altitude 5000 ft Oxygen *must* be available Move about as little as possible Doctor or nurse in attendance | Normally reject If essential, travel in aircraft pressurized at 5000 ft |
| vi Pneumonia | *Must be more than* a month since recovery | Maximum altitude 5000 ft Oxygen must be *available* *Move about* as little as possible | Normally reject If essential travel in aircraft pressurized at 5000 ft |
| vii *Pneumothorax* (artificial) | Refill must have been done more *than 7 days* ago Degree of displacement If mediastinum is fixed, lung must be not less than *three-quarters* expanded Bilateral involvement | Maximum altitude 5000 ft Oxygen must be available Move about as little as possible | Normally reject If essential, travel below 5000 *ft* |
| viii Pneumoperitoneum | Refills must not be more than 2000 ml, and must have been done more than 7 days ago | Maximum altitude 5000 ft Oxygen must be available Move about as little as possible | Normally reject If essential, travel below 5000 ft |
| ix Tuberculosis *a* Active | Danger of hæmoptysis and spread of infec*tion* | Maximum altitude 5000 ft Oxygen must be available Move about as little as possible | Reject unless sputum is free from tubercle bacilli, or any cavity is *controlled* by collapse therapy |
| *b* Healed | As proved by (i) Recent examination of sputum showing no evidence of tubercle bacilli, (ii) X-ray film *of lungs*, (iii) *Clinical* condition | Maximum altitude 8500 ft Oxygen must be available | Acceptable if flight below 8500 ft can be guaranteed |
| 12 **Tumours** | Depends on site and presence of metastases *and nature of complications* | As required by symptoms | Depends on case |

not been found to be increased by high altitude and its resultant lowering of oxygen tension

3. **Morphine.**—The advisability of the use of morphine at high altitudes is somewhat in question. It is known that morphine has a depressant action on respiration and Jones and his co-workers demonstrated that animals receiving morphine and taken to high altitudes had a much higher fatality-rate than did a control group not receiving morphine Observations on human beings who had received morphine have not revealed any serious respiratory depression when they were taken to high altitudes At present it would be wise to use morphine conservatively if there is much likelihood that the patient will be taken to altitudes of more than 12,000 ft and if there are not adequate facilities for giving oxygen on the aircraft

4. **Sedatives.**—The central nervous system depressants most commonly used are the barbiturates It is believed that the barbiturates are of help in controlling the air-sickness of that group of individuals susceptible to air-sickness who have a large psychogenic factor The drug must be administered before the onset of actual and active sickness to be of any value Drugs of this nature may be used without danger by passengers, but must not be used for aircrew, especially the pilot, any sedative being contra-indicated for aircrew for obvious reasons. Because of the sedative effect of diphenydramine hydrochloride (benadryl hydrochloride) and tripelennamine hydrochloride (pyribenzamine hydrochloride) on some persons, they should not be used by aircrew for a period of at least twelve hours before flight

5. **Streptomycin.**—Streptomycin is also contra-indicated for the pilot unless there is urgent need for its use The reason for this is that streptomycin may have a toxic effect on either the auditory or vestibular branch of the eighth nerve If streptomycin must be used for a pilot, it should be used in such a way as to obviate the toxic complications as much as possible If the dose is less than 1 g. daily, there is not a great chance of damage to the eighth nerve If it is necessary to give larger doses, complications may be avoided by giving small, divided doses more frequently and by not giving the drug for more than ten days

## CONCLUSIONS

All cases of passengers for air travel who do not conform to the accepted standards of normality should be considered on their merits and any patient requiring to travel should first produce a certificate from his doctor indicating the nature of the disease, its

severity, whether or not it is under treatment, and whether the treatment has resulted in the disease being under control It should be remembered that many doctors are unacquainted with a number of the problems encountered in air travel, and a full description of the patient, his treatment, and the extent of his disability should be requested before a decision is made In addition to this, each case should be considered in the light of the factors mentioned in previous paragraphs, and a decision made accordingly No rigid rules can be laid down, and modifications in the light of experience will have to be adopted from time to time

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## *CHAPTER XXVII*

# FLYING EMERGENCIES

## I. PARACHUTE DESCENT

**General.**—The problem of escape from aircraft by parachute at high altitude is one deserving of attention The destructive power of modern cannon shell, and the high proportion of incendiary missiles employed, resulted in aircrew frequently escaping from aircraft by parachute in wartime. This very often occurred at altitudes of 30,000 ft or more and raised immediate problems, of which the two chief were cold and anoxia Such problems

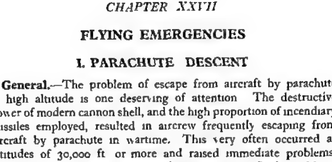


*Fig* 125 —Comparison between free and controlled parachute descent
(*Figs* 125, 126, *by courtesy of* '*Physiology of Flight*')

have been successfully met, but there have, of course, been other conditions requiring medical attention, such as wounds inflicted by enemy aircraft during parachute descent, injuries occasioned on reaching the ground, and injuries received while leaving the aircraft, but such are outside the province of this book

The speed at which a person falls through space, with and without a parachute open, is indicated in *Fig* 125. It will be seen that it is an obvious advantage for the first part of a parachute descent to be what is known as a 'free fall', in order that the airman may more rapidly escape from those heights where he is likely to

suffer from anoxia or the effects of extreme cold In addition, time must be given for the delaying action caused by the resistance of the air to a falling body to take effect, and thus minimize the shock of deceleration when the parachute is opened. In practice there are several factors to be considered, and in a cool-headed, clear-thinking person considerable delay can be effected before pulling the rip-cord which opens the parachute.

**Precautions to be observed.**—The first consideration is that the parachutist should be well free of the falling aircraft before the

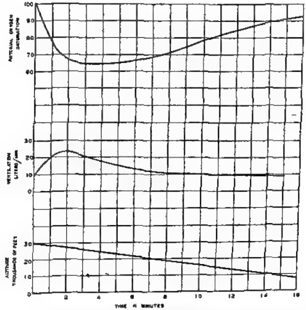


*Fig* 126 —*Saturation of arterial blood with oxygen and ventilation rate in parachute descent*

parachute is opened, as many fatalities have occurred owing to the parachute opening too soon and becoming entangled with the machine *In modern high-speed aircraft this accident is prevented* [illegible] all clear of the

Thirdly, if he bales out at such a height that he is subjected to extreme anoxia and intense cold (– 55° C at 30,000 ft. to 40,000 ft ) it is desirable that he reaches more moderate heights as quickly as possible In order to do this the parachutist executes what is

known as a 'free fall', in which, after leaving the aircraft he does not pull the rip-cord which causes the parachute to open, but allows himself to fall as quickly as possible until a pre-arranged height is reached This height may be anything between 5000 and 15,000 ft, according to circumstances, but is usually one at which the effects of cold and anoxia do not apply He then allows his parachute to open and descends in the normal manner This has been carried out successfully on many occasions, thus avoiding these two complications arising out of escape from aircraft at great heights

There are two methods of preventing anoxia when jumping from heights First, two or three deep breaths of 100 per cent oxygen before jumping from moderate heights will provide adequate oxygen for a free fall until suitable levels are reached Alternatively, all personnel should be equipped with a small 'bale-out' bottle strapped to the leg, which will provide 100 per cent oxygen for a few minutes in sufficient quantities to enable the parachutist to reach oxygen levels from great heights without a free fall if this is impracticable *Fig* 126 shows the percentage saturation of arterial blood with oxygen, and the ventilation rate of people making simulated parachute descents in a low-pressure chamber

Adequate protection against the effects of cold should be provided in the form of gloves, helmet, flying boots, and flying clothing The subject must be instructed forcibly to clear his ears in descent or trouble with otitic barotrauma (Chapter XVIII) may occur

**Deceleration Effects.**—Gravity produces an acceleration of 32 ft per second, per second If a man were to jump from a height of 4000 ft, and there were no resistance (which condition could only exist in a vacuum) his speed would constantly increase, and he would reach the ground in approximately sixteen seconds travelling at a speed of about 500 ft per second Since, however, air resistance increases as the square of the velocity, his falling speed increases only to the point where the air resistance equals the pull of gravity, when the velocity becomes constant, at approximately 130 m p h or 190 ft per second It is important to realize that the constant speed of 190 ft per second would also be reached even though he were to jump from a plane diving towards the earth at a speed of 400 m p h Travelling at a velocity of 190 ft per second, it would take him about 20 seconds to reach the earth If, however, the rip-cord of the parachute is pulled, his velocity is diminished to about 20 ft per second and he would then take about three and a half minutes to descend The force exerted by the slowing down (negative acceleration or deceleration) from 190 ft per second to 20 ft per second is equal to about 2–3 'g' as a general rule It will be seen, then, that if the parachute is immediately opened on

jumping from a plane travelling downwards, or even horizontally at high speed (400 m p h ), dangerous stresses will be exerted on the parachute and the man, which may result in the destruction of both Furthermore, travelling at a speed of 20 ft. per second, an object would strike the earth with a force equal to 6 'g' if the ground were rigid The liability to injury on landing is subject to a number of variables such as age, weight, physical fitness, strength of wind, terrain, and the practised skill of the parachutist Injuries are more frequent in those over 25 years of age and over 13 st in weight In a strong wind, or over rough or hard ground with obstructions, the risk of injury is obviously much greater Breaking the fall, by bending the knees or rolling, usually decreases this force to approximately 2-3 'g', and the risk of accident can be greatly minimized if the actions mentioned above are carried out at the moment of impact The commonest sites of injury on these occasions are the legs in 64 per cent and the head in 24 per cent of total casualities encountered The total incidence of accidents in training is approximately 0 5 per cent of total jumps (Whittingham)

**Conclusions.**—Instructions to aircrew concerning the above precautions should be quite adequate for emergencies which may arise, and no preventable mishaps should occur other than those due to unforeseen circumstances

## II. EMERGENCY ALIGHTINGS AT SEA

### GENERAL

With modern multi-engined aircraft, the occasions on which an aircraft has to make a forced descent on the sea are very rare, and actuarial estimates of the likelihood of this occurring to trans-oceanic services put the possibility as extremely remote (1 in over 33,000 crossings—McFarland) When, however, it does occur, it may well be many hundreds of miles away from land, and possibly in bad weather The chances of such an accident are, of course, increased in wartime owing to the hazards of enemy activity, and it is therefore proper that all concerned with flying operations should be prepared to deal with such an emergency The problem may be divided into two sections · first, action immediately prior to and at the moment of impact of the aircraft with the water, secondly, action concerned with subsequent survival at sea

### ALIGHTING ON THE SEA

**1. Impact Forces.**—When an aircraft lands on the sea its speed of impact will be considerable, probably in the neighbourhood of

100 m p h or more, and the sea at the time may be rough Two distinct shocks are normally felt by the occupants on such an occasion The first is caused by the tail of the aircraft striking the water and is normally light This initial shock is of some importance, since it may be mistaken for the second or main shock when the whole fuselage strikes the water The second is of much greater severity, and may be sufficient to throw passengers out of their seats, or even break the seats should they not be adequately attached to the main structure

**2. Personal Safety Equipment.**—The direction of the force acting on the occupants on such an occasion will usually be such that they will tend to be forced forwards and upwards It is therefore important that all passengers and crew should be properly strapped in their seats before any alighting on water is considered, and their life-saving jackets correctly donned, in accordance with instructions which should be given to them at the commencement of the flight This is analogous to lifeboat drill in a ship Equipment for this purpose is described in subsequent paragraphs

**3. Aircraft Flotation.**—It is unlikely that the aircraft, unless it possesses a pressurized cabin, will float longer than 5 to 7 minutes, and even this time may be reduced should there be extensive damage to the wings or fuselage In the case of a pressurized cabin, the aircraft may float for some hours before finally submerging, while flying boats can withstand considerable buffeting in rough weather for long periods, and still remain afloat

## ACTION TO BE TAKEN IN DINGHY

It is of the greatest importance for future survival that the passengers and crew arrive in the dinghy in as dry a state as possible The effect of exposing personnel in wet clothing to wind may be disastrous, as under such conditions the body temperature will fall rapidly Recent work indicates that when a body temperature of 75–77° F is reached, death ensues quickly from ventricular fibrillation

Dinghies for use in passenger-carrying aircraft should incorporate a tent-like hood carried on a collapsible mast, which will allow complete protection of personnel from wind and water A double bottom which can be inflated is usually found in modern dinghies. The provision of this is essential if protection from the cold of the sea is to be secured Not only will a double bottom help to conserve body heat, but the extra comfort which it will provide for the dinghy occupants is well worth the additional weight It must be remembered that available space per passenger is severely limited in a dinghy, and anything which can be done

to alleviate the cramped position in which the castaway has to remain will be advantageous to survival

In any disaster to an aircraft at sea, it is probable that several of the occupants will get wet owing to have fallen into the sea in their attempts to reach the dinghy. As soon as possible, this wet clothing *must be removed, piece by piece,* wrung out, and put on again The greatest possible effort must be made to protect such personnel from losing heat too rapidly.

## WATER AND FLUIDS

Of paramount importance in the survival of passengers and crew is the possession of adequate amounts of drinking water The amount of water which is necessary for the average man in a dinghy is approximately 800 c c. per day This should be just sufficient to keep dehydration at bay It is obviously impossible to provide full water rations for all personnel for the whole time which must elapse before they are rescued, and experiences in the last war indicated that rescues are usually effected within the first five days of dinghy existence, and thereafter the chances of rescue diminish rapidly Every opportunity should therefore be taken to catch rain in the dinghy apron and to store it in empty tins or containers *The first small quantity of water collected has usually* to be drained because of the high salt content, owing to the salt crystallizing out of the apron If no storage space exists, the water should be consumed There are three other ways in which drinking water can be obtained

**1. Carriage in Sterile Tins.**—These tins, which were extensively used in the Royal Navy and Royal Air Force during the last war, contain approximately 16 oz of water. In order to carry sufficient water by this means it would be necessary to have at least two tins per passenger per day The weight penalty involved in such a load would be prohibitive and recourse has therefore to be made to the second method

**2. The Desalination of Sea Water.**—The principle involved here is to remove the salts in a given volume of sea water by the addition of a measured amount of chemicals in the form of a briquette. The sea water is placed in a rubber fabric bag and is shaken up for *some twenty minut* [illegible]
tion is complete [illegible]
consists of barium [illegible]
silver oxide, which is capable of removing sulphate, chloride ions, and magnesium from sea water. At the end of this time it is squeezed through a filter incorporated in the bag Water obtained by such means has a somewhat flat and unpalatable taste owing *to*

a small amount of salts remaining in the water, and the palatability may be improved by the addition of a small amount of citric acid crystals or other flavouring agents By such a method it is possible to increase the available water fourfold, compared with the volume which would be necessary in canned water

**3. Solar Still.**—In hot climates a third method of obtaining water can be employed, namely, by means of the solar still. This apparatus may be constructed to a number of different designs, star-shaped, cylindrical, or round The outer layer consists of rubberized fabric and plastic Inside is a layer of sponge rubber which holds a supply of sea water The lid is composed of transparent semiporous material The still having been charged with sea water is blown up and allowed to float alongside the dinghy in such a position that the sun's rays strike directly on the transparent top of the still The yield from such equipment is small, however, a few ounces a day, so that many stills would need to be carried by a passenger-carrying aircraft operating in Southern latitudes

**4. Other Sources.**—Other sources of fluid which will be mentioned briefly are as follows —

*a The Juice of Fishes, obtained by chewing Raw Fish*—It was at one time advocated that the juice of fishes could form food and drink for dinghy occupants On scientific examination, however, this is obviously untenable, since the body fluid of fishes contains salts at a concentration above that of the human body Water will therefore, be drawn from the body in order to get rid of the additional salts ingested Fish juice should not, therefore, be used as a source of water and should only be consumed when an adequate supply of fresh water is available

*b Urine*—Urine is again an unsatisfactory form of fluid, containing as it does large amounts of salts The urine of castaways will of course become more and more concentrated as the amount of available fresh water is reduced

*c Sea Water*—Sea water must on no account be consumed by the dinghy occupants for obvious reasons In the acute stages of thirst, however, personnel may be allowed to moisten their lips with sea water twice a day

## TEMPERATURE CONTROL AND PROTECTION FROM HEAT

Whilst the conservation of heat is of prime importance in the Northern Hemisphere, as mentioned in a previous paragraph, in Southern latitudes the problem is one of keeping cool It has been estimated that a resting, unclothed man, in a dinghy in the

*c*. In cold water the feet may remain bright red. Usually they are yellowish-white, blue, or mottled blue-black. Dark patches or blisters may appear. The skin is easily broken.

After rescue the feet remain in this cold and bloodless state for several hours. As the circulation returns they become hot and red, with bounding pulses. Swelling increases and blisters may appear. Parts which are going to become gangrenous fail to become warm again, and aching, throbbing pains and tingling sensations interfere with sleep. After a week to ten days another kind of pain develops, similar to the stabbing pains of tabes. The distal parts of the extremities remain insensitive to touch, pin-pricks, and thermal stimuli.

3. **Grading.**—Cases can be graded according to the extent of their anæsthesia at seven to ten days. Minimal cases have no residual anæsthesia and should be fully recovered by this time. Mild cases have anæsthesia confined to parts of the plantar surfaces of the feet and the tips of the toes, and recover in ten to twelve weeks. Moderately severe cases have degenerative nerve lesions with more extensive anæsthesia as far as the ankles or even higher. Blisters may appear on the feet and legs, and gangrene, which invariably develops, may cause the loss of digits. Such cases require hospitalization for a long time.

4. **Protective Measures.**—Passengers should be instructed in protective measures to prevent immersion foot as soon as possible after alighting occurs. The bottom of the dinghy must be kept as free as possible from bilge water by bailing or mopping. Over long periods boots may constrict swelling feet and impair the circulation. If possible wet socks should be replaced by dry ones, and as soon as footwear begins to feel tight it should be removed and not replaced. No rubbing of the affected feet should be allowed once the tissues become swollen.

5. **Treatment.**—

*a. Pre-hyperæmic Stage.*—During rescue operations survivors must be carried; on no account must they be allowed to walk on the affected feet. After stripping off wet clothing, the body should be wrapped in blankets, leaving the affected limbs uncovered. Survivors may be given hot drinks, but must not be left near an open fire; hot bottles may be placed near the trunk. The feet should be raised on pillows, exposed to the air, and kept dry; *no massage should be allowed*. ... should be lightly powdered
with sulphanilamide
should be permitte
limbs should not b...
atmosphere until the circulation returns

*b. Hyperæmic Stage*.—Once the feet become hot and painful, dry cooling should be used to relieve the pain and limit excessive exudation due to a too rapid return of the circulation. An electric fan should be allowed to play on the feet in a cool room (15°–18° C.). Should this not prove sufficient, in some cases ice-bags may have to be used. The skin temperatures should not be reduced below 23°–26° C.

## III. LIFE-JACKETS FOR AIRCREW

An essential requirement for emergency use in aircraft flying over long stretches of water is a life-jacket which will keep the wearer afloat in the case of an accident at sea. The most important requirements for such a piece of equipment are as follows:—

1. The ability to keep an unconscious man's head out of the water in such a position that there will be no lolling of the head into the water whereby respiration might be endangered.
2. To be fully inflated automatically in the shortest possible time; this would entail the use of some sort of gas cylinder.
3. To turn a relaxed (unconscious) man who is face downwards in the water, automatically and rapidly into the upright position, so that there is no possibility of drowning.

It was decided at an early stage of experimentation to rely solely on gas inflation rather than kapok. The reasons for this decision are that kapok is bulky, and has to be protected by a waterproof covering, because, once wet, it is extremely difficult to dry out. Furthermore, it is very liable to become bruised, thus losing its air content and buoyancy.

At first oral inflation alone was used, which was accomplished by using a wide-base rubber tube fitted with a simple non-return valve. By this means the jacket could be inflated in some thirteen seconds from a completely empty state. It was decided, however, that whilst this time was better than anything achieved in the past, it was not satisfactory, in that an unconscious or severely wounded man would not be able to carry out the necessary procedure. It was therefore decided to use a gas cylinder, and a type widely adopted consists of a cylinder of carbon dioxide, acting on a similar principle to that found in a 'sparklet' soda-water syphon. These cylinders have the advantage that the gas can be sealed in them in a more efficient manner than other methods. The method of releasing the gas is simple and sure, depending as it does on a cutter-valve piercing the gas seal in the cylinder. An alternative method of release is a manually operated valve.

Research carried out during the war has stressed the need for adequate protection of the back of the neck and occiput in cold

water Early prototype models of flotation jackets showed that the righting properties would have to be improved, and that the head must be well supported so that it is kept out of the water. In order to approximate to this ideal it would be necessary to have the object in a vertical position in the water. The only method of carrying this out would be to enclose the neck in a large inflatable collar This was the method adopted in some of the early experimental types of life-jacket, but examination revealed the fact that it was not entirely practicable, owing to the vertical motion induced, and that the ideal position for the wearer was that which maintained him in the water at an angle of 45° from the vertical It was agreed that the ideal life-jacket must be comfortable, and it was thought unlikely that such a collar as was used on the original jackets could ever be produced in a form suitable for general issue; the latest form of life-jacket provides a compromise between the vertical and horizontal positions.

One jacket is made in the form of a quick-donning waistcoat, and consists of a two-piece stole extending from either side of the chest, connected at the back of the neck It can be put on easily and simply in the same manner as a waistcoat, and is secured to the body by means of a belt of webbing which passes under the arms and unites across the front of the chest The webbing is prolonged across the centre of the back in order to provide a means of lifting the wearer out of the water Three lightning fasteners are provided to approximate the two buoyancy chambers together, the upper fastening of the three being padded in order to support the chin of an unconscious man (*Fig* 128)

The jacket has been tested with subjects under conditions of unconsciousness The subject was anæsthetized, and, after endotracheal intubation, placed in the water wearing the inflated jacket. First he was allowed to float freely on his back In this position the nose and mouth were well clear of the water. He was then placed face downwards in the water, the object being to observe the righting qualities of the jacket Not only did the subject rotate with considerable speed, but the attendant swimmer found it difficult to hold him in the face-downwards position at all

On the basis of these experiments the following requirements were laid down as being essential for a satisfactory life-saving jacket and, with certain modifications, are the standards adopted to-day for civilian and military use —

1 It must provide a buoyancy adequate to support a 250 lb person for at least 12 hours

2 It must support a relaxed man in an almost upright position with the head inclined slightly backwards.

*Fig* 127.—Life jacket floating conscious man

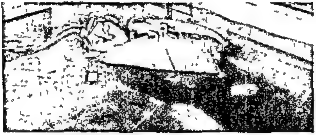

*Fig* 128.—Life jacket floating unconscious man

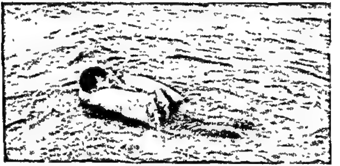

*Fig* 129.—Life jacket with conscious man in deep water with force six wind blowing. The position here is not ideal. The head could with advantage be at a greater angle with the surface of the water.

(*Figs* 127-129, *Royal Air Force photographs. Crown copyright reserved.*)

3. It must keep the back of the neck and occiput of a relaxed man out of the water.

4 It must turn a relaxed man who falls face downwards in the water automatically and rapidly into the position outlined in paragraph (2) above

5 It must be capable of being speedily and easily donned and adjusted Recent models are equally effective when put on correctly, upside down, inside out, or back to front.

*Fig* 130 —Latest type of life saving jacket for use in civil airlines (*By courtesy of British Overseas Airways Corporation*)

6 It must be suitable for a man to wear when at work and in action

7. It must be of such a shape as to enable a man wearing it (uninflated) to pass through an escape hatch or an armoured door.

8. It must be easily foldable into a convenient shape and size for storage.

9 It must be durable and of hard-wearing quality

Life-jackets based on these specifications should be effective in preserving life for considerable periods even in rough open seas Tests of certain types of this equipment are demonstrated in *Figs* 127–129

An improved type based on further trials and experiments has recently been adopted for use in some civil airlines and is shown in *Fig* 130

## IV. ESCAPE HATCHES

A necessary feature of all aircraft is the provision of adequate escape openings which can be used by passengers or aircrews in case of emergency Such openings can be in the roof, floor, or sides of the aircraft, and usually have a quick-release mechanism, whereby a complete panel falls out, or, in some cases, a piece of perspex which can be broken

It is important when considering the minimum dimensions for such openings to remember the following factors —

1 The aperture must cater for the largest person likely to be carried

2 Passengers may be [illegible]

3 It is likely that [illegible] if the accident occurs at [illegible] given

4 The average passenger is untrained at such manœuvres

5 There may be panic

In view of these possibilities the following factors should be borne in mind when designing escape hatches —

1 Approaches thereto should be clear and unobstructed

2 Their location and method of operation should be clearly indicated, and as simple as possible

3 When opened, protrusions and jagged edges should not be present, which might catch in the clothing or life-jacket and prevent rapid exit

4 Dimensions and shapes recommended should be approximately as follows —

*a Roof hatches* Elliptical in shape, not less than 20 × 26 in Foot-rests should not be more than 25 in below the opening

*b Floor hatches* Elliptical or rectangular in shape, not less than 20 × 30 in

*c Side openings* Rectangular or elliptical in shape, not less than 52 in high and 26 in broad, with a minimum height of not less than 34 in from the floor

Handrails and protective coverings should be provided in suitable positions wherever possible

The above dimensions are considered desirable on the basis of a large number of anthropometric measurements made when originally considering this problem Experiments conducted at

the time indicated that over an equal area the ellipse is to be preferred over other shapes, where ease of exit is the paramount consideration

## V. PROTECTIVE CLOTHING FOR OCCUPANTS OF SINGLE-SEATER AIRCRAFT

Experience gained during the war showed that the protection of aircrew from exposure after coming down over the sea must be carried on the person. It is obviously impracticable that an impermeable suit should be worn all the time, and with this in view a lightweight, one-piece suit which could be readily inflated with warm air was designed

It is essential to keep the weight and bulk of such a suit to a minimum, and at the same time maintain the maximum flexibility and impermeability to water, which objective was ultimately obtained by means of a continuous rubber film spread over thin cotton fabric, the whole of which can be fully inflated with warm air in a space of two to three minutes. The necessary structural strength is obtained by 'quilting', in which adhesion of the two layers is achieved by spot-welding with rubber solution.

The suit completely covers the wearer with the exception of face and hands, and methods whereby it can be quickly removed by rip-strips are incorporated, should the suit become waterlogged or it is desirable to remove it for any other purpose In addition, drainage tubes are provided at the heel of each foot The complete suit weighs less than 2 lb and can be readily folded and carried in a convenient form over the wearer's shoulder A large degree of flotation is provided and any imprisoned air goes first to the top of the suit thereby ensuring that the airman is not retained in the inverted position in the water One size only was manufactured at first on the basis of a large number of anthropometric measurements and in practice was found to cover the needs of all users The material is usually dyed a bright yellow colour to attract the attention of rescue parties, and although only used in the latter stages of the war undoubtedly contributed materially to the saving of a number of lives which might otherwise have been lost through exposure

## VI. EXPERIMENTAL WORK ON THE EFFECTS OF COLD AND IMMERSION

Much work was done during the recent war on the effects of chilling the human body, both in this country, the United States

of America, and in Germany, some of the results of this wo are given below

**1. Effects of Varying Temperatures on Life.**—In water belc 15° C (59° F) death from cold occurs within an hour, often a few minutes In water at 32° C (89° F) the body can mainta thermal equilibrium only by shivering, and since the warme ocean temperature is about 28 8° C (84° F) death from chilli eventually supervenes even in the tropics

**2. Subjective Symptoms.**—Persons placed in a bath of wat at 2–12° C suffered intense pain, especially if the neck ar occiput were immersed, but after 5–10 minutes the intensity perception of pain lessened The muscles, especially of t' arms, developed a rigidity, occasionally interrupted by cloni tonic convulsions Speech became difficult. The respiration-ra increased greatly at first but after 20 minutes dropped to abo 24 per minute Respiration was prolonged and difficult, and lat rattling and stertorous Foaming at the mouth sometimes occurr early at body temperatures of 32–35° C, but had no prognosi significance Relaxation of muscular rigidity was always unfavourable sign

**3. Consciousness.**—Consciousness became clouded when t rectal temperature reached 31° C The pupils dilated, t response to light diminished, and the gaze was fixed upwarc After removal from the water, deep reflexes were much exaggerate despite the rigidity of the muscles

**4. Cardiovascular Changes.**—The face became pale, lat cyanotic Veins did not collapse and venepuncture was possib The pulse-rate quickened, at first to 120 per minute, but once t' rectal temperature fell to 34° C the rate gradually slowed to per minute At 29–31° C the rhythm became irregular, b still slow. A change from a slow to a rapid irregularity was n unfavourable, and during the rewarming often preceded a retu to normal rhythm In all fatal cases sudden standstill of the hea followed irregularity of the slow type In this connexion it h been noted that temporary auricular fibrillation has been observ in flyers picked up after immersion in cold water

**5. Rectal Temperature.**—The rectal temperature fell gradual to 35° or 36° C and then more steeply. It took about 70 to minutes to reach 29 5° C Even after removal of the subject fro water, the rectal temperature continued to fall at the same rat sometimes for as long as 20 minutes, usually causing an additior loss in body temperature of 4° C It was thought that this 'aft drop' might account for the delayed deaths ('collapse deaths') shipwreck survivors, which occur 20 minutes to one and a h

hours after successful rescue. In general, death occurred at body temperatures between 24° and 26° C., and in several recorded instances after periods of from 53 to 106 minutes

**6. Skin.**—Skin temperature fell rapidly at first, reaching 12° C. in ten minutes, then more gradually until the final drop occurred When the neck and occiput are immersed with the rest of the body, the rectal temperature falls much more rapidly than if these parts are kept above water. Moreover, cerebral œdema may develop, and the cerebrospinal fluid pressure rise to 400 mm of water

**7. Blood.**—There was hæmoconcentration, with an increase in red blood-cells and hæmoglobin of from 10 to 20 per cent Leucocytes increased to about 26,000 per cu mm but not parallel with the increase in red blood-cells. Increased viscosity in the blood occurred early and was already evident at temperatures of 35° C Blood-sugar increased by 80–100 per cent, the curve being a mirror image of the temperature curve. There was no overflow of sugar into the urine.

**8. Alcohol.**—Alcohol, prior to exposure, increased the rate of body cooling somewhat, but in one severely intoxicated subject seems to have delayed the onset of cardiac irregularity. During re-warming a small amount of alcohol may assist in accelerating peripheral vasodilation but its value is doubtful This question needs further investigation

**9. Sugar.**—Sugar consumed before and during exposure reduced the rate of cooling Re-warming could not be accelerated by sugar intake, but subjects who had taken sugar before or during exposure warmed up more quickly than those who had fasted.

**10. Resuscitation.**—

*a Heat*—Experiments showed that the most effective therapeutic measure for persons cooled to the verge of death by immersion in cold water is rapid re-warming. Re-warming had to be rapid to cushion the 'after-drop' in temperature, which continued to fall for ten to fifteen minutes after the subject was removed from the cold water The subject was undressed and immersed for at least ten minutes in water at 40° to 50° C, then rubbed with dry towels and put between hot blankets Dry rubbing was of no value without preliminary warming to relax the skin vessels If after ten to fifteen minutes the rectal temperature had not begun to rise progressively the hot-water treatment was repeated

In the case of those awaiting their turn for treatment or for whom hot baths are not immediately available, hot water at 55° or 60° C may be poured over the clothing Severely-chilled persons were not burned by water at this temperature

In three extreme cases a bath in water at 50° C was successful, even though heart and respiration were at a standstill In no case was there any indication that hot baths were injurious During recovery there was a change from a slow irregular pulse to a rapid irregular one, which in about one and a half hours gave place to a normal rhythm Once the stage of rapid irregularity is reached the subject is out of danger, and in three cases even heavy work did not delay the recovery of normal rhythm Consciousness returned more quickly than with other methods of treatment Muscular rigidity relaxed and respiration became easier

Mere wrapping in blankets gave poor results With electric light cradles the results were not much better and there was a danger of uneven heating with areas of excessive vasodilatation, resulting in dizziness and nausea The danger of burning the insensitive skin was increased if the subject was having tonic-clonic convulsions Diathermy was tried, but it was difficult to warm the body evenly throughout

The first to advocate rapid re-warming was Leptschinski in 1880 In 1942 Binhold (Kiel) reported that in cooled rats the best results were obtained by warming first in dry air for ten minutes at 37° C, to allow adjustment of the circulation, and subsequently in hot water Other results obtained suggest that a preliminary period of dry gradual heating is undesirable

*b Drugs*—Drugs such as strophanthin, metrazol, coramine, and lobeline were ineffective if not actually harmful This is in agreement with the findings of Jarisch (Innsbruck), who found that these and other stimulating drugs, including benzedrine and caffeine, were toxic in cooled animals

**11. Comment.**—The carbon-dioxide content of both arterial and venous blood was diminished Oxygen saturation was not measured, but at autopsies made immediately after death it was noticed that blood in the right heart was a very dark red, that in the left heart very bright red The urine showed increased specific gravity, decreased chlorides, and traces of albumin Cerebrospinal fluid pressure was increased usually by 50–60 mm but occasionally was over 400 mm of water

Death from immersion in cold water was attributed to heart failure, heart failure resulted from —

*a* Increased viscosity of the blood

*b* Increased peripheral resistance due to vasoconstriction

*c* Cooling of the heart muscle, rendering it hypodynamic There was maximal dilatation of the right heart

The decreased peripheral resistance which follows rapid re-warming is beneficial and not harmful as was once supposed

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# Part IV. PSYCHOLOGICAL CONSIDERATIONS

## CHAPTER XXVIII

# METHODS OF STUDY

### I. INTRODUCTION

The psychological problems concerned with operational flying have assumed increasing importance in recent years The reasons for this are many The strain imposed upon the human system by modern flying conditions is infinitely greater than it was a few years ago, and more particularly so than it was in the first world war At that time flights were of short duration at moderate heights, and the whole technique of flying did not demand the tasks of co-ordination and concentration which it does to-day Furthermore, whether the aircraft is a single-seater fighter or a multi-engined transport aircraft with a large crew, the responsibilities of a pilot are essentially individualistic Whatever the circumstances, the ultimate decision is a lone and solitary one, and the responsibility for himself and others, for the successful execution of his task, and for the avoidance of catastrophes is very personal When flying, particularly as pilot, there is little or no opportunity to relax for one moment An error of judgement may be fatal, a delayed decision imperil the whole crew and many passengers, a mistaken assessment of conditions result in grave error, as judged by results

Physical disabilities are relatively easy to diagnose and treat, psychological ones not so easy Both, however, are closely interdependent, and it is unwise to concentrate on one to the exclusion of the other Detection in the physical sphere is not infrequently demonstrated by symptoms in the psychological A correct assessment of the relative importance of symptoms is very important, and the likelihood of psychological states being the source of organic symptoms must always be borne in mind It is therefore of the greatest importance that the care, prevention, and detection of such disorders by medical officers should be taken in hand at the earliest possible opportunity

The aircrew medical officer in the closest possible daily contact with the persons under his care, is best qualified to note early changes, and, by his knowledge of the personality with which he

is dealing, make a valuable contribution to the correct line of treatment to be adopted To allow a case to progress to the stage where evidences of strain are clearly established may court the risk of an accident, or end a man's flying career prematurely

A factor which should always be borne in mind when dealing with people who fly, which is not always appreciated by people on the ground, is that from the time of take-off to the time of landing not a single moment is allowed for relaxation. One thing you cannot do in the air is nothing.

When discussing psychological considerations it is not easy to decide on the best method of nomenclature or arrangement. There are no preconceived ideas or methods which can be used as a guide A straightforward arrangement or division after the manner of accepted text-books on medicine or surgery is not suitable. The nomenclature is not yet fully established, the diagnosis in some cases not entirely convincing, and the values of varying forms of treatment have not yet been assessed sufficiently to put on an accurate comparative basis In the six years of war, however, certain indisputable facts have emerged, and an attempt will be made to divide this section of the work into appropriate headings, [illegible]

chapters on preselection and training because of the profound importance that *they ultimately play in determining a person's* ability to stand up to the flying stress imposed under operational conditions Of necessity, in subsequent chapters the material used, and the observations and recommendations made, apply *largely to wartime operational flying, although many of them are* equally applicable to civil flying problems, but it is hoped that with the advent of peace similar material will be avilable to formulate recommendations which are applicable to the problems *arising in commercial aviation* It will be noted that much use has been made of the valuable material provided by Symonds and Williams in connexion with this problem, to whom full acknowledgement is made elsewhere.

## II. METHODS OF INVESTIGATION

A very desirable prerequisite of accurate, psychological investigation and assessment, is that the medical officer should have an intimate personal knowledge of the patient, and this fact has been recognized by many authorities, who have repeatedly emphasized the value of such a person's opinion compared with that of a person with a greater theoretical and practical knowledge, but considerably

less personal knowledge, of the person being reported on, or the actual conditions under which he lives and works The aircrew medical officer will not be a specialist, but, if well chosen, he will be deeply interested in the people under his care He will know their shortcomings, their ambitions, their difficulties, and their powers of combat and recovery This knowledge can only be obtained when he lives with them as one of themselves If he eats, sleeps, drinks, plays, flies, and suffers with them, he will be well placed to judge the relative merits and demerits of a particular case In this connexion the question of a medical officer going on operations arises, and many authorities are convinced of the importance of this factor, if an opinion is going to be of real value It is difficult to appreciate the relative importance of the hazards inherent in operational work unless they have been personally experienced, and at the beginning of the war, the Germans, appreciating the value of this factor, employed it to a greater extent than the Allies, with commensurate success Its discontinuance by them was brought about at a later stage by lack of medical man-power

The many complicated factors giving rise to mental strain may reveal themselves in a variety of guises which, if not recognized early, may develop later into true psychological illness In order to be able to recognize them, and to institute the necessary remedial measures, it is necessary to have some understanding of their symptoms and aetiology While this has been described in many textbooks, the particular circumstances with which we are concerned had not been considered in any great detail prior to the 1939–46 war

Psychoneurosis is a form of illness characterized by the appearance of mental and physical symptoms for which no true organic basis can be discovered, and which are therefore presumed to be psychological in origin. Evidence of mental disharmony will give added weight to this conclusion Care must be observed, however, in concluding that, because no organic basis has been observed, a purely functional disease is the correct diagnosis Cases of doubt will always occur Furthermore, care must be taken that mental stress is not over-emphasized by the patient in order to hide existing disabilities Thus, the basis of approach to these cases should essentially be unhurried and unbiased, with a complete picture of the domestic, personal, temperamental, and operational factors in their correct proportions Only thus can a true perspective be obtained and a correct evaluation of symptoms estimated

With this object in view, a personal record of every member of aircrew who comes under a medical officer's care is invaluable It can be unofficial, and not restricted to medical or professional knowledge, the intention being to present as accurate a picture

as possible from day-to-day observations of each subject's make-up  Two examples of these cards are shown in *Tables XXIV, XXV.* In practice these records can prove of great value, and

*Table XXIV*.—Personal Record Card

*(OBVERSE)*

Operational Card No ..

| | | | |
|---|---|---|---|
| J 5707 | S/Ldr | "J D A" | Pilot |
| "A" Flight | | Canada | 12/14 |
| Single | Flight Commander | | Bank Clerk |

| Medical | Psychological | General |
|---|---|---|
| | Extrovert | Very keen. Good leader. Lacks experience in judging men |

*(REVERSE)*

Operational Record

| Sorties | Incidents |
|---|---|
| IIIIIIIIIIIIIIIIIIIIII—22 | 11 7 44 Severe damage from A A A/C holed Morale shaken<br>14 8 44 Observer killed, cannon-shelled Pilot O K<br>17 8 44 Killed doing single-engine landing at Brussels |

there can be included in them any apparently trivial comments or observations, which, at a later date, may prove to be of great interest and help  It is important to stress the necessity of continuity in these observations. A medical officer in charge of

aircrew should remain on one station for as long as possible. Thus will he be able to be with each person from the time he arrives on the station to the time he leaves. A fleeting knowledge or casual

*Table XXV*—PERSONAL RECORD CARD

(*OBVERSE*)

| | | |
|---|---|---|
| OPERATIONAL CARD No<br>33107 W/Cdr "R T B" Pilot<br>O C Squadron D F C<br>Married, 2 children Cranwell | | |
| MEDICAL | PSYCHOLOGICAL | GENERAL |
| Jaundice '24<br>P U A 42<br>Amœbiasis '43 | Schizophrenia '40<br>Depression '41 | Needs support and restraint Lacking in self-confidence I Q —, over-compensated Impulsive Inferiority complex Very susceptible<br>Posted T T C 1 3 45<br>C O useful |

(*REVERSE*)

| | |
|---|---|
| OPERATIONAL RECORD | |
| SORTIES | INCIDENTS |
| IIIIIIIIIIIIIIIIIIII—20<br>IIIIIIIII—9 | 8 11 44 Lateral instability syndrome<br>13 11 44 Single engine return<br>27 12 44 Attacked by 3 M E 109 fighters, port engine on fire returned very shaken |

acquaintance is not adequate structure on which to build an accurate psychological picture.

Such a subject as the one under review should obviously be divided into the more elementary, but very important, work

conducted by the observer on the spot, the medical officer in charge of aircrew, and that done by the more highly qualified and trained psychiatric specialist. The task of each is different, but complementary, and neither can work satisfactorily without the other. Together they can integrate an overall programme of investigation and treatment which can be of great value, and was undoubtedly largely successful in dealing with the many operational flying problems which arose under war conditions.

Subsequent chapters are not intended to deal with the problems in detail, or to provide expert opinion in such matters—that is the task for the specialist Rather is it an attempt to clear up some of the present misconceptions which exist, and help towards a clearer and more logical approach by the average medical officer to these most important problems met with in flying personnel as a means towards their solution or amelioration

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## *CHAPTER XXIX*

# AIRCREW NEUROSIS

## NOMENCLATURE

The nomenclature of aircrew neurosis is not easy, partly because in many cases new ground is being broken, but also because care has to be taken to avoid the use of existing terminology which has grown up with casual usage, and which is not always strictly related to correct psychological interpretation The majority of cases, however, fall into one of several fairly clearly defined groups, and in most cases symptoms have been such as to afford straightforward categorization, although in some instances there is inevitable overlapping from one class to another

1. **Anxiety State.**—This comprises the largest proportion of all cases of aircrew neurosis, totalling nearly 80 per cent of all cases seen

2. **Hysteria.**—A much smaller number of cases came under this heading, but this section leads the list of the other neuroses, which altogether only make up a small percentage of the total

3. **Depression.**—Is the outstanding feature in a smaller number of cases

4. **Obsession.**—Schizophrenic and fatigue syndrome represent the remainder

A particular term, originated by Flack in the 1914–18 war and used by Symonds and Williams in their researches in the R A F, which covers the many causative factors that may produce any of the neuroses enumerated above, and which will be referred to throughout, is 'flying stress' It will be described in detail later

## STATISTICAL

The particulars given below are in no way intended to be complete and are approximate only They cover only a relatively small field Accurate figures from all sources are not yet available and it will be a considerable time before complete, worthwhile statistical analyses are published from which authoritative deductions can be drawn They do, however, furnish a current estimate of the

situation *taken from a representative cross-section* of wartime operational personnel. Civilian figures have not been computed.

**1. Personnel affected.**—Personnel working in bombers presented the largest proportion of those suffering from aircrew neurosis, being represented by half of all cases seen In this respect it must be remembered that the number of air crew personnel in bombing forces is very much larger than those in fighters, almost all of which are single-seater aircraft. Of all personnel, those working by night form a much larger percentage of cases than those working by day This result is in line with what might be expected, as, in general, it may be said that the strain and hazards of operations by night are greater than those by day. Of the individual aircrew personnel affected, pilots dominate the scene by a large majority. This is understandable by reason of the additional responsibility and strain this member of the aircrew always has to carry.

**2. Aetiology.**—Psychological causes produced an overwhelmingly large majority of all cases, the figures being well over 90 per cent Investigations in the last war into aircrew neurosis on a small scale by Anderson, Gotch, Birley, and others, indicated that 18 per cent of cases of flying disability were of psychological origin Flying stress (discussed in detail later) ranks high as a causative factor, while predisposition plays an important part in assessing a pilot's liability to break down Domestic factors are high in the list of aetiological considerations. Of all cases seen and treated, over 40 per cent were returned to full flying duties

## PRESELECTION

**1. General.**—In the 1914–18 war flying was in its infancy, and no system of psychological preselection was carried out, but in the later stages this was recommended by Birley and others, although *only the most elementary outline of the principles involved* was considered Subsequent to that period, there was at that time a tendency to emphasize a man's physical fitness rather than his psychological fitness for aircrew duties This is quite understandable in view of the necessity of certain physical characteristics to ensure satisfactory flying ability. The Germans were quick to recognize the importance of preselection, but, as is often the case in their scientific attainments, they carried this theory to an impracticable extreme, and their results were neither encouraging nor productive of adequate numbers of aircrew. Early in World War II the Americans approached the matter with great zeal and instituted an extremely *complicated system* of psychological

standards, which, however, in practice proved very inelastic, the result was a high rejection rate, and subsequent tests showed that many rejected candidates later became successful operational pilots despite a low psychological assessment. A difficulty encountered is that the standards required vary with changing circumstances. Thus the personality traits required to fly a fairly simple open aircraft at relatively low altitudes are not adequate to fly a highly-complicated technical machine, like a modern aircraft, over long distances at great heights by night. Navigational aids, operational requirements, and scientific advances have changed the environment in which modern aircrew have to work, and therefore, rigid standards would have to be subject to constant review in order to be of value.

**2. Psychological Interview.**—This is undoubtedly valuable but its importance must not be over-estimated. In one short interview, with no previous knowledge of the candidate, it is manifestly impossible for anyone, however brilliant, accurately to forecast whether or not a person will make a good operational personality, and attempts in the past to utilize this method have failed on account of the high wastage rate involved, which at one stage amounted to over 80 per cent. It is even less satisfactory in wartime, when the number of candidates is greatly increased. It is, however, very important in eliminating the clearly-cut unsuitable cases, such as those presenting a bad family or personal psychological history. Such cases have been proven in practice to be heavily predisposed to neurotic breakdown under operational conditions, and eliminating them by reference to their medical history, or as elicited by an interview, will save a lot of trouble at a later stage. There is no doubt, however, that the vast field of vocational selection which has been developed to such a high degree in recent years will be invaluable in the future for selecting civil aircrew for particular duties, particularly when the sources from which they are largely drawn at present, namely, the fighting services, no longer provide the candidates required. Briefly summarized, it may be said that a psychiatric interview is of great value but should not, except in the clearest cases, be the determining factor in a candidate's acceptance or rejection. Flack has stated (1930) that successful aircrew must have a satisfactory blending of psychological characteristics, such as determination, will-power, motivation, etc., as well as such physical characteristics as satisfactory cardiovascular and central nervous systems. Accurate evaluation of these can only be made when judged as a whole, not separately.

**3. Early Psychiatric Tests.**—Innumerable tests of this sort have been devised, of which a few may be mentioned in passing.

The 'startle' test was instituted to estimate a candidate's response to sudden commotional disturbance, and he was subjected to sudden startling noises when carrying out a task requiring co-ordination and calmness, such as carrying a glass of water, etc. Mental alertness was judged by his reactions to certain questions and situations His reaction time was observed under varying conditions. These tests were not, however, found to be reliable, as many candidates who failed on these tests turned out to be perfectly satisfactory aircrew material at a later date.

4. **Assessment.**—In the assessment of any candidate at a preselection interview the following factors, subject to certain individual variations, may be taken as a broad guide —

*a Unfavourable Factors which predispose to Neurotic Breakdown* —

1 A bad family history of neurotic illness in either parent, brothers and sisters The inclusion of less close relations need not be considered

2 A childhood history of previous neurotic traits, such as fear of the dark, secretiveness, childish phobias, and fears or avoidance of companions

3 A history of nervous breakdown, or any psychological calamity

4 A candidate's description of lack of confidence in himself, or his ability, or doubt of his own competence to carry out tasks allotted to him

5 Lack of motivation, temperamental instability, or existing phobias, as seen subjectively or objectively on examination.

*b Favourable Factors* —

1 A good family history with no evidence of neurotic predisposition

2 No childhood history of fears or phobias, and a happy unspoiled youth

3 No history of nervous breakdown or nervous troubles.

4 Good motivation behind the desire to fly and operate.

5 A confident, intelligent, resolute character

The above assessment is only a generalized one, and should be assessed in conjunction with other factors such as physical condition and the extent to which a patient appears to be overcoming any disabilities which may have been observed

5. **Ideal Requirements.**—No fixed rule can be laid down for the assessment of a candidate's suitability for aircrew duties No standards yet devised have proved satisfactory under all the conditions under which they have been called to operate. Each case must be judged on its individual merit. In America the 'Stanines' test for selection and classification of wartime operational aircrew has been extensively tried and a considerable

degree of accuracy claimed for its findings It is now being applied *for an experimental period to civil aviation requirements* and comment on its value at this stage would be premature In the Cambridge Cockpit test (described elsewhere) an attempt is made to assess a candidate's reaction to simulated flying conditions, with special reference to fatigue and the introduction of pilot errors in performance Evaluation of this test to date would appear to indicate an encouragingly close relationship between the prognosis of a candidate's flying career based on the results of his performance in the test, when compared with his subsequent operational history Such results justify further investigation and research along these lines Symonds, Williams, and others have done extensive research on the question of aircrew preselection in the Royal Air Force in wartime, and the results of their observations and those of others will undoubtedly form the basis on which future methods of assessment will be built up, modified from time to time, in the light of experience Until an accurate system of preselection is evolved, based on a large number of representative cases covering a wide field, which have been followed up subsequently, it would be wiser *to confine prognosis to the results of close observation of a candidate* during the period of his flying training This does not preclude elimination and preselection of the more straightforward cases prior to flying training, but it should be stressed that, whenever doubt exists, the services of a psychologist specially trained and versed in flying problems should always be obtained For economic reasons it is obviously more desirable that selection should take place by means of an interview, but it would not appear that this is always a practical solution of a difficult problem, and it will be some time before an entirely satisfactory method of preselection for aircrew is evolved

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## CHAPTER XXX

# AIRCREW NEUROSIS (*continued*)

## SERVATION PRIOR TO OPERATIONAL STAGE

### I. THE OVER-ALL PICTURE

E observations made at this stage are of great importance in icating a candidate's future career Here may a shrewd estite be made of his outlook on the whole performance The didate is seen with his companions, under similar conditions, lergoing the same experiences, and subjected to the same varying rees of bewilderment, excitement, and apprehension It is here t the foundation for the future will be laid and the early nptoms of an incipient neurosis seen, and where it is vitally portant to eliminate any unsuitable types before their own idition might influence any of their fellows It is interesting v quickly any latent psychological complications with regard to ng manifest themselves once a person is on a station where ng is actually taking place The whole atmosphere on such a tion is different, the conversation, the work, and the life in neral is directed to one object, namely, that of getting candidates o the air, and this evident force moving in the new life in ich a person now finds himself crystallizes any feelings he may herto have managed to hide

### II. TRAINING

**1 Reaction to Flying.**—Now is the first opportunity to observe person's actual reactions to flying Hitherto his proclaimed bitions and flights of fancy have been purely theoretical, now ey are going to be translated into hard facts The majority of rsons when starting to fly show obvious excitement mingled with lesser degree of apprehension This is usually quickly replaced the sheer thrill of flying A confidence in aircraft and instructors uickly banishes early fears With some, however, this is not An obvious apprehension at the outset is increased with mulative flying experience They become more and more ghtened each time they fly It is obvious that they dread the

prospect of going into the air, and the condition progresses, so that they can be observed brooding upon it when not engaged on flying duties, and their whole life comes to be dominated by this morbid anxiety Others are secretive about their reactions to flying They either refrain from any comment or manifestation, or in one way or another exhibit an obviously exaggerated casualness or braggadocio about the whole affair which clearly belies their real feelings The trained observer can quickly note these manifestations and can accordingly watch doubtful candidates for further developments

2 **Progress.**—

*a Initial Training* —Here may be observed a pilot's reactions to progressive training in elementary flying. Having had his first experience of travel in a new element, he now settles down to the serious business of controlling this strange and rather wonderful object Too much emphasis must not be laid on specific reactions to training, as here, almost more than anywhere else, individual characteristics will play their part in determining a person's progress, without in any way altering the final issue, as is true of training in any subject One person will be slow, methodical, plodding, another will be brilliant and swift; a third will be spasmodic so that on one and the same day he may be the alternate pride and despair of his instructors Setbacks are inevitable in almost every case at one stage or another, and the wise instructor and experienced medical officer will endeavour to form a broad overall picture of a candidate, rather than be influenced by isolated incidents in his career Some pupils are readily adaptable to the changing conditions in which they find themselves, some find that they have a particular aptitude for certain types of aircraft; some, who are not mechanically minded, find the maze of technical terms and mechanical theories invoked almost more than they can encompass in the early stages A hasty, unconsidered judgement in these cases would be most unwise.

*b Advanced Training* —The pupil has now learned to fly. He has an elementary knowledge of navigation, the theory of flying, the control of a simple aircraft, and some of the more elementary technical engineering problems associated with flying On reaching the advanced training stage several new elements are introduced Hitherto he has flown simple, light, easily-controlled aircraft His instructor has always been at hand to advise, encourage, and correct He has always flown in good weather, under ideal conditions, with a minimum of hazard. Now many other elements of risk are introduced He will learn to fly more complicated, larger aircraft, perhaps with more than one engine.

Every feature of flying will become a more intricate procedure Navigation is introduced, and he will learn to fly over country which is unknown, by day and by night, a task which involves not only flying the aircraft, but using navigational instruments and maps Bad weather will constitute a large hazard that he will meet, with all its attendant fears and doubts, and which will tax to the utmost his confidence in his own ability, the reliability of his aircraft, the accuracy of his instruments, and the wisdom of his instructors. This is a real test of a pilot's staying power If he comes successfully through this period he will proceed to an Operational Training Unit where, by graduated stages, he will fly the actual aircraft to be used on operations, under similar conditions, and with every attempt made to simulate the problems which will arise when he is actually flying against the enemy Thus an imperceptible metamorphosis takes place whereby the fledgling pilot, fearful of his first excursion into the air, becomes a competent master of his aircraft, capable of dealing with emergencies and problems as they arise, and of making decisions affecting the welfare of many people besides himself, a person confident of his own ability, and capable of transmitting that confidence to others flying with him

c *The Pupil-Instructor Relationship* —This is of vital importance in training and its value cannot be overestimated Just as a good schoolmaster looks first to himself if a pupil is not making progress, so too, when a flying pupil does not show signs of promise, one of the first investigations to be made is into the ability, temperament, and experience of his instructor Instructors are very carefully chosen and trained, and the usual standard is extremely high, but, despite this, incompatabilities of temperament between instructor and pupil are bound to occur, and it is usually the pupil who suffers Sometimes the decision is an easy one to make, as, for example, when several pupils under the same instructor all have trouble, but there are other cases when the decision is extremely difficult and experience has shown that in many cases the only solution is to fly with both, first as a pupil with the instructor, and secondly, as instructor with the pupil By this means the diagnosis is very much facilitated Thus it may be found that a good instructor is getting fatigued and irritable and needs a period of rest, or a pupil is not making progress because of some elementary misunderstanding which can easily be seen by someone looking at the problem from a new aspect. One of the more common causes of trouble is that of speech Attuning one's hearing to conversation through the intercommunication system in an aircraft when there is noise and

which the very reverse is true. The reason for this transfer should be ascertained He should be flown with at the earliest opportunity and his reactions to the new type of flying noted.

*c Those starting a Second or Third Tour of Military Operations* — Almost everyone in this class will be doing so at *his own request* and will, therefore, in all probability cause the medical officer little concern except on two accounts. Great care should be taken to see that persons of recognized enthusiasm and keenness

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they are lost The good medical officer will be adamant in his *representation about removing such personnel from flying at the* very first signs of fatigue, because in these cases, although the symptoms are often well hidden at first, they subsequently deteriorate very rapidly An occasional, but by no means rare case, is that of a person who, unknown to anyone but himself, and perhaps the medical officer, has been *operating in desperation* under the strain of domestic or other non-flying difficulties These persons are in effect introducing a form of therapy which in many cases is successful, but at the same time they must be nursed and watched carefully for the earliest signs of fatigue These early reactions on arrival at a station, if observed and recorded by an intelligent medical officer, whatever his primary deductions may be, can be of great use later on, when a decision of vital importance *to the person concerned may have to be made.*

**2. Off Duty.**—A medical officer's duty is not confined to working hours, to the boundaries of the camp, to the operational activities of the squadron, or to the mess He should endeavour to participate in all the off-duty activities of aircrew, if he is to obtain a complete and accurate picture of the persons under his care Among other things of which he should take particular note are the following —

Does a man keep regular hours or does he go to bed very late? *Is there evidence of his not having slept well at night?* Is the sleep undisturbed, or has the subject complained of restlessness, nightmares, or lack of adequate hours of sleep? Does he appear to enjoy his food? Does he eat what is set before him with relish, or is he a constant absentee at meals; when present, only toying with the food put before him? Is he an abstainer, a moderate drinker, or a heavy drinker? Does he, as most young men do, indulge in a relatively harmless glass of beer, with occasional care-*free parties of over-indulgence, or does* he consistently drink more than is good for him? Does he drink with obvious distaste, for pure effect, or does alcohol release the inhibitions which otherwise

restrain his behaviour? Is he a heavy smoker? Does he smoke occasionally as a social habit, or when he is nervous and apprehensive, as before operations? Does he play games, either of an individualistic nature such as golf or tennis, or communal games such as rugby, cricket, or football? Does he look as if he would like to play but does not do so because he is shy or secretive? Is he married, and if so does the partnership appear to be a success? Is he fond of talking about his wife and children? Does he obviously pine for them, or does he appear not to care? Has he any worries in connexion with his family such as his wife's pregnancy, the illness of children, domestic disharmony, or other marital problems, which he may well be glad to talk over with a sympathetic and understanding medical officer? Experience has shown that domestic problems feature very largely as aetiological factors in early stages of anxiety state in aircrew, and financial obligations entailed by a family often play their part in this respect The summation of any or all of the factors enumerated above helps to form a general picture, against the background of which reactions may be assessed in their true perspective

**3. On Duty.**—Here a man may be judged when actually doing the job for which he is posted to the unit, and the truest picture may be formed of his attitude to the task in hand At the earliest opportunity the medical officer should fly with the subject, the following points in a person's flying are worthy of note Is he a flashy, sensational, occasionally brilliant, occasionally careless, pilot? An extrovert, anxious to satisfy himself and everyone else of his own superiority Or is he conscious of his own shortcomings, and consequently a little over-cautious, with a tendency to underestimate what ability he has? Is he frankly a bad pilot, but (and this is a most dangerous category) apparently quite unaware of it, or is he the perfect type so sought after by the executive, the consistent pilot, whose results are uniformly good without being brilliant? Here it must be stressed that there is a considerable difference between purely technical as opposed to purely operational ability A man may be an indifferent pilot, but excellent on operations, or he may be quite outstanding technically, and very little use on operations The perfect combination, of course, is the one who combines a successful blending of both of these qualities

When operating with a pilot a primary consideration is whether he is a good leader and has the confidence of his crew Do you feel confident flying with him? Do others feel the same? Has he a name for consistency, reliability, cheerfulness, and wisdom in an emergency which has saved many a crew from death? Has

be confidence in his own decisions and does he enjoin patience and loyalty on those under him, even though his decisions appear on their face value to be incorrect? Or is he a vacillating, uncertain, eccentric character, whose moods can never be predicted, whose reactions are untrustworthy and uncertain, and whose decisions, because they are so often subject to change, are unreliable and do not beget confidence?

How does he carry out the less exciting, more routine, but very important tasks on the ground? Is he concerned for the welfare of his crew, their quarters, their recreation, and their domestic problems? Is he meticulous and conscientious, and does he deport himself with behaviour befitting his position?

Does he fare well in adversity? When the weather is bad, targets heavily defended, the loss rate is high, and squadron morale in placed on a fine knife edge, is his the influence which will be exercised in the right or wrong direction? These and many other questions will be constantly in the mind of an interested medical officer, and from the answers he obtains, a shrewd general picture of a man's operational value may be built up.

**4. At all times.**—

*a Temperament and Disposition*—Care must be taken not to attempt to place anyone in certain hard-and-fast categories with respect to temperament and disposition because people of widely dissimilar character may carry out an identical task in different ways with equal success A classical example of this, quoted by Birley, is the late Dr W G Grace and Prince Ranjitsinhji, both of whom were utterly dissimilar in every way, but achieved equivalent outstanding success at cricket So many different types of temperament are met with in successful pilots, which are apparent contradictions to one another, that it is impossible even to attempt a classification of the typical characteristics of a good or bad one. As has been stated before, a person's aptitude for flying does not necessarily indicate suitable temperament for operations. In such cases the quality of personal observation on the part of the medical officer over a period of time, on the ground and in the air, is a valuable contribution which can be made to a person's flying assessment

*b. Intellect*—Here we are on slightly firmer ground, and for pilots in particular, many authorities consider that the higher the degree of intelligent application to the problem of operations, the more likely is success to accompany the effort, and the greater the probability of overcoming difficulties inherent in this type of work This is a difficult assertion to prove, but in practice is frequently shown to be true.

*c* *Stamina*—This is a factor which has been recognized as important by all connected with operations. Staying power, or the ability to persevere against physical, meteorological, and psychological adversity is a quality which pays excellent dividends in the long run. Stamina is a quality which appears to be uninfluenced by environmental conditions, is innate, and to a large degree unvarying Because it is unsensational it is often overlooked and its relative value underrated, in practice it cannot be overestimated

## CONCLUSIONS

Observations made along the lines indicated should enable a medical officer to form am accurate overall picture of individual aircrew personnel, evaluate their positive and negative qualities proportionately, and perceive any early physical or psychological deterioration which, if dealt with in the preliminary stages, may give relatively little trouble, but which if left until too late may be disastrous to the person concerned, and others as well

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## CHAPTER XXXI

## AIRCREW NEUROSIS *(continued)*

### FACTORS INFLUENCING PSYCHOLOGICAL DISORDERS

### I. PREDISPOSING CONDITIONS

### A CONSTITUTIONAL FACTORS

**1. Personal Predisposition.**—Predisposition is of fundamental importance in the aetiology of [illegible]
to date show that nearly 70 p[illegible]
respect show evidence of its [illegible]
personal history augurs ill for the subject's future A family history, on either side, *of nervous breakdown, mental disorder,* or any other neurotic tendencies should be regarded as unfavourable, and doubly so if the personal history indicates an inheritance of these traits A history of fear of the dark, childish phobias, avoidance of companions at school, absence of self-confidence, or nightmares persisting from childhood into adolescence, show a character which in practice has been found to be heavily predisposed to breakdown under operational conditions, and should consequently be viewed with suspicion

**2. Co-ordination.**—If, owing to diminished co-ordination and sensitivity of the sensory mechanism, a person is not capable of instantly translating into appropriate action the varied stimuli he may receive on operations, it is highly probable that he and his aircraft will be casualties There is often little or no time to think in an emergency, and the pilot who will give his crew confidence is one who acts almost before the occasion which demands it arises, so instantaneous is his response to the stimulus of danger signals

**3. Intelligence.**—Without adequate intelligence capable of coping with the many varied problems as they occur, a man will not survive long on operations which present constantly-changing situations, demanding rapid thought and swift decision, Intelligent application of knowledge to the circumstances in which a person finds himself is absolutely essential to successful aircrew work, and mere slavish imitation or repetition of lessons taught is worse than useless under such circumstances.

**4. Confidence.**—Confidence (as opposed to over-confidence) which cannot be transmitted to the crew is a fatal omission in a responsible aircrew member This is repeatedly experienced when flying with seasoned pilots, who manage in an imperceptible way, although surrounded with every possible adverse contingency, to fight with danger, and instil into all connected with them a sense of quiet confidence and assurance, which sets jangled nerves at rest, dispels doubts and dismay, and produces a much more efficient working team.

**5. Timidity.**—This, on the other hand, is the keystone of failure, and is recognized almost the moment a man gets into an aircraft This should not be confused with genuine fear and apprehension, which is present in almost everybody on military operations Timidity is shown by lack of confidence in oneself, the aircraft, the weather, or one's crew, a state of mind which spells disaster at an early stage Williams describes it as a lack of aggressive tendency, which, with its associated drive, stamina, and will to carry on, might be summed up in the word 'pugnacity', it is a most undesirable trait in a person engaged in fighting with a resourceful enemy, or any fortuitous combination of adverse circumstances

**6. Introspection and Morbid Fears.**—This condition, with its associated attitude of self-recrimination, flying 'post-mortems', and the associated doubt and depression which go with it, are serious barriers to successful work Morbid fears, phobias, and obsessions, which occupy the mind, detract from concentration on the task in hand, and very few cases which break down in this way, and which have a bad constitutional predisposition, ever return to flying, many cases have been seen in which an effort was made to return such a person to flying, only for him to break down again at a later date

### B ACQUIRED FACTORS

**1. Operational.**—It is here, actually on operations, as might be expected, that the full force of the factors operating against a man come into play, and as such they may apply while flying, or only on the ground

*a Fatigue*—This has been dealt with in detail in a previous section of this work (Chapter XXI) A majority of observers are agreed that the contribution of fatigue to psychological disorders is very great, and care taken to eliminate this factor bids fair to eradicate the onset of flying neurosis Organic disease can also play its part, but in these cases the symptoms are usually manifest either to the medical officer or the subject himself before they give rise to psychological symptoms. A man in a good state of physical health

is better able to resist fear and its consequences than a man in a lowered state of fitness, and this would be adequate reason by itself for ensuring that all aircrew fly only when they are physically as fit as possible Experiments in the decompression chamber, submitting people to prolonged periods of anoxia, show great similarity to the mental condition engendered by a low state of health, in which there appears to be very little resistance to adverse factors or fear-producing conditions

*b Fear* —This is the overriding factor in operational flying It is present in all persons at some time or another in their lives, and is governed by a variety of complex psychological factors which may hide it, suppress it, supplement it, or give way before it, according to the character of the individual. Fear is an honourable condition, which no honest person would deny experiencing at times Fear is a forerunner of the anxiety state, which is its commonest manifestation in operational aircrew. In early flying there is usually no real fear, merely an apprehensive thrill which is later overcome and conquered as confidence in the aircraft, the instructor, and ultimately oneself is gained It never disappears completely, however, and is always present in varying degree, only needing a small stimulus to produce an exacerbation There may be a precipitating cause, in which latent or dormant fear becomes manifest—including such incidents as an unpleasant accident, domestic upset, or a sudden realization during a period of inactivity, when there is time for contemplation, of the risks run, hazards faced, or uncertainty of preservation of life. Many aircrew with whom the question of fear has been discussed have quoted examples such as these, as bringing to the surface a fear which they knew existed, but by resolution were able to keep under control

*c Morale* —This factor has a profound influence in encouraging or retarding incipient fear, and its importance justifies a separate chapter on the subject (Chapter XXXIII) With high morale the incidence of aircrew neurosis is low, with low morale the reverse is the case Where there is high morale in a squadron, potential cases of breakdown are often carried along by the enthusiasm and spirit of the squadron as a whole, but where morale is poor no such stimulus exists

*d Environment* —A person's reaction to fear is, on many occasions, governed by his environment There are very few people indeed who are not susceptible to fear, but the degree to which it is developed is determined by a person's temperament and attitude towards it, which in turn is heavily influenced by his surroundings. Thus on many occasions a medical observer will see a pilot whom he knows really well apparently exhibit no signs

of fear whatever under conditions of extrem
everyone else present was very frightened and h
as well  Discussion afterwards revealed that
frightened, if not more so, than the others, but
feeling for the sake of his crew, which he did n
Similarly fear experienced by a person is greatly i
company in which he finds himself  Thus, a per
frightened will be sustained and encouraged by the
attitude of his companions, while if any evidenc
uncertainty is observed in other crew members, su
spreads very quickly, and may rapidly reduce the mo
band of persons to a very low state

*e Frustration*—Frustration is a contributory facto
duction of aircrew neurosis  Frustration in achieving
operation, in attaining a desired decoration or reward,
a desired status or position, or frustration in operational p
tends to lower morale, with the resultant increased
psychological deterioration

*f Anticipation*—All aircrew are agreed, that in wartime
the most trying time from the point of view of nervo
with the exception of the actual operational hazards enco
is that following the time of briefing until they take off, wh
know the target, the weather conditions to be expected en
and the opposition which it is anticipated will be encou
Under the best possible conditions this period may be abou
minutes  Under the worst, due to changes of operational
gramme or unexpected delay, it may be three to four hours
the mental strain of reviewing the forthcoming hazards is
siderable, particularly to anyone with a vivid imagination
fertile brain  Most aircrew are agreed that they would infini
rather get into an aircraft not knowing where it was going or w
it was doing, than have a period of suspension when there is n
a lot to do except think about it  This period is a time whi
taxes all temperaments, but is particularly hard on those no
possessed of good stamina and morale  The relief of tension whe
the word comes through to get ready for take-off, or alternately,
of the cancellation of a sortie, is most striking

*g Inactivity*—There is no doubt that to keep personnel working
hard is an excellent antidote to incipient psychological breakdown,
and long periods of inactivity, caused by the weather or other
considerations, are a definite predisposing factor in breakdown
Many persons can date the beginning of their trouble to a quiesc
period, and state that had they been consistently and
ing, the condition might have been pre

*h Spacing of Targets*.—At first sight it would appear that operational necessity would preclude the organization of crews so that they would not be called upon to operate over difficult targets on successive nights, but in practice it has been found that this can be done. The added strain of personnel operating on a

the executive, who did not appreciate its value, but in the later stages of the war it was so marked as to be unmistakable.

*i Accidents*.—These undoubtedly are precipitating factors in incipient cases of psychological breakdown, but their influences are variable and at times it is quite surprising how little effect they have compared with other times. On one occasion in which the morale of a squadron was low, and there were several pilots for whom concern was felt, there were seven major disasters in the course of four hours within a few miles of the airfield and it was thought that this would precipitate a crisis. In actual fact the very reverse occurred, the explanation of which it is difficult to understand.

*j Lack of Confidence*.—Lack of confidence in the operational commander, the captain of the aircraft, the aircraft itself, or its maintenance, are potent factors tending to lead to breakdown, and on many occasions change of an obscure key person among ground personnel has prevented the development of a difficult situation in this respect.

*k Self-reproach*.—This has been an uncommon but not unknown cause of trouble, usually occasioned by some accident, for which, rightly or wrongly, the person holds himself responsible, in which perhaps a friend or acquaintance was killed, or some damage done, which has created this feeling in the subject's mind. Here again a friendly and co-operative approach in the air and on the ground, as well as talking the whole thing over, may well dispel what would otherwise be an ever increasing obsession in a conscientious person's mind.

*l Matching of Personalities*.—The factors bound up with this question are difficult to assess in so many words, but are none the less real, and are productive of unsatisfactory results if not correctly dealt with at the start. They concern the matching of appropriate personalities, so that there is a harmonious integrated team rather than a number of isolated individuals forced to work together. The 'round peg' in a 'square hole' personality will quickly break down if there is predisposition and other factors tending to cause

it, whereas were this factor to be watched, and, where possible, eliminated early on, it might never give rise to trouble This is particularly noticeable in the composition of crews On many occasions squadron commanders have been concerned over the question of an individual with whom they were not satisfied but on whom they could fix no specific adverse label Investigation has shown a good operational record, with no physical disability, but at the same time an undoubted potential psychological breakdown impending The improvement has been very striking on changing the person round to another crew The same applies to a flight, a squadron, and to a lesser degree to room companions, all of which factors may easily be overlooked as being too trivial to deserve serious attention

**2. Domestic.**—Home affairs, marital disharmony, illness, pregnancy, and finance are factors which are not normally associated with flying efficiency, but any adverse circumstances in this sphere play a profound part in a man's ability to resist psychological breakdown, and for this reason it is right that a medical officer should be as well acquainted as possible with this side of a man's life, and material benefit will follow attention to such details as giving a man leave to overcome an apparently small domestic crisis, which, if left unattended, may well be a dominant factor in breakdown at a later stage

**3. Training.**—Many a pupil has been turned out with a gross underestimation of his own flying abilities, due to the facetious or occasionally malicious attitude of his instructor, or the unintentional ridicule of his friends over some apparently trivial misdemeanour, which has grown in the telling and preyed upon the subject's mind In many cases of this sort it will be necessary to fly with such pupils two or three times in order to assure and reassure them that their lack of confidence in themselves engendered by this bad training was unjustified In fact, the only way to give them complete assurance in this respect is to operate with them, because only thus can they really be certain that you are willing to commit yourself totally into their care The attention of all those responsible for training should be drawn to the necessity of preventing such a state of affairs being allowed to develop at that stage, because its effects may not be apparent until some time later This does not mean that just rebuke, or occasional sarcasm, [illegible]

[illegible]

sensitive persons, or when such an attitude might have a permanently adverse effect

## II. SYMPTOMATOLOGY

### A OBJECTIVE

The first signs of the onset of aircrew neurosis are almost always noticed by friends and companions of the person concerned, and usually consist in small changes in behaviour and temperament. His conversation, hitherto smooth and unrestrained, may lack its previous cogency and ease of expression. A previously amiable and placid disposition may change to an irritable and nervy one. From being interested in flying topics, he begins to lose interest, and appears not to care for such things. His keenness on the actual work in hand shows an appreciable diminution, and associated with this, his squadron or flight commander will report a slight but definite lowering of efficiency Aerial photographs are not quite so good, his timing does not show previous accuracy, his crew are not quite as well briefed as hitherto, his flying lacks polish, schedules are not so scrupulously observed His appearance and mode of dress may noticeably alter One who has been impeccable in his turnout tends to become careless or slovenly

A greater alcoholic consumption than his fellows is not a sure diagnostic sign, a change in consumption is Thus a person's consumption may show a marked increase, or one who has been accustomed to drinking a certain amount consistently, stops drinking altogether The important thing to notice in these cases is that there is a change from normality, as previously observed over a period of time In each case the change will be different, and no precise rule can be laid down as to what symptoms are positive and what are negative as long as the alteration is realized to be significant There are certain objective symptoms which will probably be noticed only by a medical officer, or they may be forcibly brought to his attention Thus, one case reported that a very minor sprain of the thumb made it quite impossible for him to manipulate the throttle controls, a disability which in no way affected his performing other manipulative feats without pain or discomfort A second one complained of a sore throat immediately he turned on his oxygen, while a third stated that he was unable to control the rudder-bar owing to a stiff knee, which in no way affected his playing squash and tennis, or prevented him from swimming or cycling Taken as isolated factors, such symptoms would have no significance, but in conjunction with other observations they all go to form a complete picture

### B SUBJECTIVE

**1. Physical.**—Digestive disorders are the commonest features reported in the majority of cases. Anorexia, flatulence, dyspepsia,

abdominal pain, and regurgitation of food are common symptoms Sleep is often affected, the person complaining that he has difficulty in getting off to sleep although tired Sleep is not restful and he is liable to nightmares, and wakes up early, not feeling rested. Headaches are a common feature, usually temporal, less often occipital, in location Various visual symptoms are met with, such as difficulty in focusing on instruments, blepharospasm, pain in the eyes, photophobia, and excessive lacrimation. Defective night vision is a not uncommon symptom Fatigue is often complained of, the patient saying that he feels quite unable to carry on, is too tired to play games, and lacks energy to go for a walk or go out in the evenings In a few cases personnel complain of symptoms of oxygen lack, although the apparatus was turned on to full flow at moderate altitudes

2. **Mental.**—They all complain of failing powers of concentration, and inability to keep their minds fixed on the objective This may result in wandering off course, not keeping an accurate time table, failing to maintain flight log, and, on occasion, complete mental 'black-outs' during flying, their attention being suddenly recalled by another member of the crew Lack of memory for simple facts is often quoted, and a symptom to which pilots are particularly prone is increased irritability and shortness of temper

3. **Psychological.**—A gradually increasing lack of confidence in himself, the aircraft, his crew, his superior officer's ability and judgement, or of the organization to which he belongs, and of which he has hitherto been an enthusiastic member, is a classical early sign, and at a later stage a feeling of frustration and inability, and the worthlessness of carrying on Persons affected in this way are quite unsusceptible to logic and argument, and will persist in maintaining their point of view despite obvious discrepancies in their reasoning Nightmares are not infrequently complained of, frequently of a terrifying nature, and at a later stage depression, phobias, and obsessions make themselves manifest Paranoia is not uncommon

### C SYMPTOMS NOTED BY THE SUBJECT BUT CONCEALED BY HIM

Investigation into many of these cases often reveals the fact that a number of symptoms had been observed by the subject himself, but, either because he was frightened or because he was anxious to carry on at all costs, he had not indicated his awareness of their presence to anyone else He may, if he is conscientious, be the first to observe the lowering of his efficiency and keenness He may be well aware of others' lack of confidence in him, he may not care whether he operates or not, although he would be the last

to show it, he may be conscious of ennui and fatigue and a feeling that all his work is a waste of time. Above all, subjects are conscious of an ever-increasing fear, which, starting only at certain times when hazards are great, increases to include the whole of a flight, *at a later stage a chronic anxiety state persists all the time.*

## *D* WHERE SYMPTOMS ARE NOTICED

As will be seen from the preceding paragraphs, many of these symptoms are vague and at times almost imperceptible, and a constant watch on all phases of a man's life is necessary on the part of the medical officer in this respect He should be on the look-out in the mess, in the consulting room, and, most important of all, at those times immediately concerned with operations Of these the most important is when actually flying This is an extremely critical time for observation, and needs considerable experience for full value to be gained from it Facial expressions cannot be assessed when behind an oxygen mask, and the analysis must be made from the general attitude of a person to the operation in hand, his conversation, and his execution of the tasks before him. Exaggerated concern over small variations in instrument readings, doubt as to the correctness of navigator's reports, increasing queries to the gunners as to the presence of enemy aircraft, undue concern as to the sound of his engines, the weather, his petrol supplies, and, as already stated, an increasing irritability and shortness of temper with other members of the crew, should all be noted. Apparently unjustifiable causes for abandoning a flight, such as over-heating of an engine or a slight fault in the instruments, all lead one to consider the question of the development of an incipient neurosis.

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# CHAPTER XXXII

# FLYING STRESS

## A INTRODUCTION

FLYING stress is not a clinical entity It consists of a set of factors peculiar to flying, which in varying combinations may produce breakdown The degree in which these factors operate varies with each case, and it is not easy to classify them, but those given hereunder are such as experience has shown to have the greatest importance in many cases of aircrew observed. In reviewing this subject it is difficult not to be repetitive, as the problem of flying stress includes many subjects discussed in other chapters, and elimination of many of the causes is an integral part of the preventive treatment Nevertheless it has been thought pertinent to include them here They are not listed in order of importance, and in some cases are only mentioned in passing, as they are dealt with in detail elsewhere

## B FACTORS PRODUCING STRESS

**1. Enemy Opposition and Unpleasant Experiences.**—There is no doubt that, whatever other unfavourable influences may play their part in producing flying stress in wartime, the question of active opposition on the part of the enemy is the biggest single factor operating in this respect Those who fly on military operations realize the sudden, unprepared-for relaxation of tension and relief associated with getting clear of the target area It is not until afterwards that it is realized to what an extreme pitch persons are wound up on these occasions From the time of crossing the boundaries of enemy territory, when searchlights and anti-aircraft guns begin to make themselves unpleasant, when the presence of hostile fighters is a constant menace, up to the target area, where all these factors are intensified ten or a hundredfold, when the aircraft may be hit or on fire, when aircrew see their friends either parachuting down or, with their aircraft in flames, exploding in mid-air—all such conditions present a bombardment of the emotions which requires great control to overcome When to this are

added personal hazards encountered in their own aircraft, such as wounded crew members, a damaged aircraft, or the possibility of landing in hostile territory or having to take to their parachutes, the psychological effect is profound. However stable a personality may be, whatever the reserves of stamina, however unfertile the imagination, there is no doubt that the intense psychological trauma of operations cannot be endured by one individual for long at a time, or on frequently repeated occasions, without signs of strain beginning to make themselves evident, and for this reason proper spacing of easy and difficult targets is of great importance

**2. Accidents and Loss Rate.**—These two factors combined together exercise a profound effect on flying stress The comradeship of an operational squadron is very close, and to come back at night to a room devoid of a close companion, particularly when his aircraft may have been seen going down in flames, is a considerable strain, and much tact and wisdom on the part of a medical officer and others is required to ameliorate these factors This is discussed more fully elsewhere.

**3. Responsibility.**—Responsibility lays a heavy load on young shoulders in an operational unit Decisions have to be made on the ground and in the air which may vitally affect the success or failure of an important operation, and the awareness of this fact shows itself in the seriousness with which the average executive officer undertakes his duties In addition to flying himself and playing his own part effectively, he may have to be responsible for the planning of an entire operation, necessitating the selection of crews, decisions as to the method of attack, time, execution, and the safe return of all personnel taking part. This constitutes very searching demands upon persons who, in civil life, may never have had to make any more important decisions than how they would spend a summer holiday They have a dual responsibility: first, to their superiors for the efficient execution of the task allotted to them, secondly, to the crews under their care and jurisdiction The crews must not be called upon to perform impossible tasks, they must be duly repaid with praise or blame as of right, and their welfare must be considered when they have completed their task

**4. Fatigue.**—This is dealt with in detail in Chapter XXI, and further recapitulation is unnecessary, but it should be stressed that all observers are agreed that fatigue is one of the most important factors in the production of flying stress.

**5. Anticipation.**—This has been mentioned already and must not be disregarded as an important factor in flying stress A

prolonged wait following the briefing for a raid on a heavily-defended target has a demonstrable effect on people's nerves, already fairly highly strung Observations on personnel prior to setting out on important missions give support to the undoubted strain of waiting on such occasions

**6. Frustration and Lack of Success.**—A series of successful sorties is a great stimulus to morale, and, contrariwise, frustration, due to cancellation on account of bad weather, or high policy, or failure to reach the target for other reasons, is a fruitful source of trouble Pilots have repeatedly said they would rather do two completed operations than one uncompleted one, and the state of mind on return from an uncompleted mission is adequate proof of this contention

**7. Ground Organization.**—The importance of this was not fully realized in the early stages of the war, and in many ways a bad ground organization can bid fair for first place in factors tending to produce flying stress in operational aircrew in conditions of war or peace Efficient flying control staff will bring a badly damaged aircraft with disrupted communications down in safety in the worst of weather It is more than comforting on returning to base under such conditions to be greeted by capable, confident, self-assured directions, which can be trusted and implicitly obeyed *Conversely, hesitant, equivocal, or uncertain assistance at a time* like this, greatly adds to the strain of an already harassed crew Further organization, ensuring immediate transport from the aircraft to a warm room, followed by good food and properly equipped accommodation, can be of great assistance to morale Few things can be more depressing on return from a flight than to stand on a cold wet airfield, apparently neglected and forgotten, to be picked up some time later and given unappetizing food

**8. Weather.**—The strain of flying long distances at night in bad weather is considerable Constant attention to the aircraft controls on the part of the pilot, repeated adjustments and alterations of course, and the added hazard of flying hundreds of miles through cloud, and possibly thunderstorms or icing conditions is considerable When to this is added extreme cold, the result is a formidable array of factors producing stress The weather at base on return is particularly relevant Crews appear to be able to withstand every possible setback during a trip, but if on return conditions for landing are bad, the strain on all concerned is greatly increased First, it is a fruitful source of accidents Secondly, all are tired and in need of food and sleep. Thirdly, the psychological reaction after having returned from a difficult operation, only to be defeated by bad weather over their own

airfield, is particularly dismaying. Some pilots have gone so far as to rate this as highest in importance of factors producing flying stress. In this respect the vital importance of a perfectly drilled ground staff to assist on these occasions and reduce all element of risk to a minimum, cannot be over estimated.

**9. Temperature Control in Aircraft.**—Inadequate heating, in the opinion of many, adds to flying stress. To be warm adds to a sense of well-being, confidence, and stamina, and the value of attention to details of aircraft heating, clothing, and hot drinks in flight, all bear out this contention.

**10. Living Conditions.**—The importance of this factor was also not fully appreciated at one time, but has been abundantly proved to be worth more than passing consideration. Poor billets, badly cooked food, and uncongenial conditions all add to the adverse factors which produce flying stress.

**11. Organic Disease.**—Any illness which lowers a person's standard of physical fitness will increase the liability to flying stress, in the same way as it has been shown to do in other spheres of life.

**12. Lack of Confidence.**—Lack of confidence in the aircraft, the crew, the pilot, or ground maintenance staff, all add to the strain experienced. In one squadron the problem became an acute one due to certain troubles with hitherto reliable engines, which troubles could be traced to faulty maintenance. The matter began to assume serious proportions, until, on consultation with the squadron commander, an entire maintenance crew was changed, with an immediate improvement in the outlook and morale of the aircrews concerned.

## C. FACTORS DETERMINING REACTION TO STRESS

**1. Predisposition.**—This is the predominant and outstanding factor. It is highly probable that a man who is predisposed to psychological breakdown will ultimately get it. Whether or not the breakdown is nipped in the bud, prevented, or so dealt with that it is overcome, does not alter the fact that a badly predisposed individual will inevitably break down, whereas a well-predisposed individual will stand up to great strain before showing any signs of breakdown. Those cases with a bad psychological history, either familial or personal, should be eliminated at an early stage and removed from flying duties. Experience has shown that it is waste of time to endeavour to patch them up or give them a rest, because they invariably break down again at a later stage. Cases with a

sound psychological background, however, and a healthy history free of neurotic tendencies in childhood, or in either parent, are encouraging material, and usually yield good results

**2. Temperament.**—This is a particularly difficult factor to estimate with accuracy, and widely different temperaments can produce the same degree of resistance to adverse circumstances If a general opinion were taken on observations made, it would probably be said that on the whole, the phlegmatic, rather unimaginative type stands up to more strain than the nervous, imaginative, more intellectual type On the other hand, it may be that one does not reveal the condition so easily as the other, and many observers have been surprised at the prolonged resistance to strain which has been demonstrated by numbers of apparently highly strung, nervous individuals Initiative is of great importance, because it furnishes a man with an instrument for dealing with his condition when it arises If he has no initiative he may well be overcome by circumstances before he is aware of their surrounding him

**3. Morale.**—By reason of the close comradeship in a squadron, many a waverer has been upheld by the high morale it possesses Conversely, if morale is low, individual weaknesses show up much more quickly It is difficult to assess to what extent morale actually affects individual breakdown, or whether a person is merely carried along by his companions, but frequently the judicious transfer of a person showing early signs of neurosis to a crew or flight with high morale, has been the last ever heard of that patient's condition, and on more than one occasion awards for valour have subsequently been won

**4. Leadership.**—This is the paramount factor in the morale of a squadron and is dealt with in detail in a separate section on this subject (Chapter XXXIII) Good leadership means high morale, with a high degree of resistance to stress, in combination with other influences which have been discussed under that heading, and, of course, vice versa

**5. Discipline.**—Discipline does not mean undue severity or driving persons beyond their capabilities It does mean that when decisions are made concerning the carrying out of tasks, nothing is allowed to stand in the way of their execution, and this factor, which is closely bound up with leadership and morale, also plays its part in decreasing a man's liability to weakening in the face of adverse factors

**6. Training.**—The importance of this was not perhaps adequately realized in the early stages of the war, but a well-trained squadron or crew is a well-disciplined one A well-disciplined one

has a good leader, and that means good morale, with all that it implies Slackness in training breeds a casual approach to all problems, a lack of self-respect, and an absence of keenness and enthusiasm for the task in hand, all of which increase a man's susceptibility to flying stress

**7. Success.**—Every squadron commander prays for occasional success, if for no other reason than for the new lease of life it gives to a squadron, and observations on the effects of this are most striking A successful attack on a difficult target under adverse conditions has an influence which cannot be judged in any way except by results, and many cases of personnel whose future was in the balance have been resolved by a successful sortie of this sort.

**8. Reward and Praise.**—Pride in success of achievement is natural and understandable, and lack of recognition a bitter blow. Words of encouragement and praise spoken at the right time are a tremendous incentive to further effort, and, coming from the right person, act as a tonic to flagging interest or wavering keenness It is striking what a change comes over a squadron when a few decorations for valour are awarded, and the psychological value of such a fact must not be overlooked

## *D.* PROGNOSIS

***1. Recognition and Treatment.****—It is important, if not essential,* to deal with these cases immediately the earliest signs make their appearance, and encouraging results are obtained when this rule is observed Delay in recognition allows the disease to become *established, other factors may be introduced,* and the subsequent decline becomes more rapid

**2. Source of Symptoms.**—Where the latent or manifest causes of breakdown are flying ones, they will be more difficult to eradicate than non-flying ones, by reason of the very nature of the subject's ... ded as hopeless and

in the right manner can often be satisfactorily dealt with, or eradicated at an early stage, and the condition does not progress

**3. Co-operation and Confidence of Patient.**—An intelligent patient with whom the symptoms, and the causes leading up to them, have been freely discussed, and who appreciates the situation, ...

problems were frankly discussed ...
tunity, and methods of dealing with them proposed and adopted

A sincere endeavour on the part of a patient who has a clear appraisal of the situation frequently results in great improvement; on the other hand, an unintelligent, unco-operative patient will rarely do well Either they do not want to get better or do not understand how they can help themselves, and treatment of such cases is extremely difficult, the results are disappointing, and their retention on aircrew duties is not justified Many patients, however, can help themselves considerably once they are given an insight into their condition, which in many cases they are frightened of, and do not fully understand A point should always be made of explaining, in simple terms, the factors surrounding the situation, and those leading up to it, and such details as can be of assistance in overcoming it No patient will co-operate if he is mystified by a series of long-sounding words or medical phrases, his condition is likely to get worse rather than better

**4. Time of Occurrence.**—Those showing signs of breakdown early in their operational career, unless there are exceptional mitigating circumstances, should not be further considered for aircrew duties, as the outlook is poor Exceptions to this rule are those cases where the condition is brought about by extreme operational hazard at an early stage, and the whole question should always be considered in the light of such circumstances If the *breakdown occurs late in an operational career the outlook is* better, the inference being that the person's stamina had resisted adverse conditions for some considerable time and may be expected to recover with suitable treatment Alternatively he may have been endeavouring to deal with the condition, the presence of which he recognized, without great success, not having had the benefit of expert professional advice

**5. Status.**—On the whole, officers offer a better prognosis than non-commissioned ranks Whether this is because they are better fitted to co-operate in their own treatment is debatable, but on the whole they bring a more intelligent appreciation to bear on the problems presented and the number of cures in this class is appreciably higher than other ranks

## *E* DIAGNOSIS

No inelastic list of signs and symptoms can be laid down, and only in the school of experience can such cases be diagnosed with accuracy Close, constant, and repeated observation is necessary, and the elimination of organic causes for a person's complaints must be conscientiously and diligently verified before a diagnosis of neurosis is considered The outstanding difficulty

for a medical officer is not so much to decide between the organic and functional diseases, as between the functional disease and a case of *pure malingering or lack of moral fibre*. The only way a diagnosis can be accurately established is by an intimate knowledge of the patient and a frank and full discussion of all symptoms, which task should never be hurried or lightly dealt with If possible the discussions should range over several days, at times mutually agreeable to the medical officer and the patient A knowledge of the patient's flying ability and reactions should be obtained by flying with him, if possible on operations Further assistance can be obtained from the opinion of other members of his crew, or his immediate superiors. Opinions gained in this way are often valuable guides, but care must be taken to distinguish honest opinion from biased thought. Lastly, opinion should be assisted by a medical officer's personal experience, gained from watching the person concerned at briefing, in the mess, in leisure hours, when flying on operations, and at subsequent interrogation

Isolated symptoms are of no use A complete, integrated picture, in which all the facts are seen, all the external factors being brought to bear are known, and all the internal powers of resistance can be calculated, will result in a diagnosis which is accurate enough to be fair to the patient and his colleagues, and will ensure the best choice of treatment for the condition Interpretation of symptoms is not always easy, in that under the abnormal circumstances of their work and environment, it is sometimes difficult to form a basis on which an assessment of degrees of stress can be estimated. A very helpful method recommended by Symonds and Williams, and which can be equally well applied to military or commercial conditions, is based on the following considerations :—

1 Whether the nature and intensity of the man's symptoms were greater than those of his companions subjected to the same conditions of stress

2 Whether his ability to carry on with his duties was greater or less than his companions

3 What was the attitude adopted by the patient to his symptoms, and the duties he was called on to perform, and the relative importance he attached to his responsibility as a member of a team, as opposed to his personal feelings

4 What was the patient's attitude towards his own treatment, or the will to persevere, and did he endeavour to help himself overcome his disability

5 What amount of predisposition there appeared to be present, and the extent of its influence on the present condition

6 The patient's operational record Whether he had just started, was well on in a tour, or was nearing the end of a second or third tour How he had conducted himself on operations—whether he had just scraped along or had gained distinction and respect for his work

## *F* TREATMENT

Perfection in treatment is obviously impossible, because in many cases the causes are due to the exigencies of the moment, some of the more important factors are discussed below —

**1. Medical Officer.**—None but first-class medical officers really interested in the work are of practical value in caring for operational aircrew, and they should be primarily selected with these qualities in view rather than for academic or clinical distinction The good medical officer will so integrate himself with the life of the squadron that he is one of them If not flying, he will be at briefing, take-off, interrogation, meals, sports, and any other squadron activities, because only thus will the first barrier be broken down, whereby a person suffering from any form of stress can feel perfectly free to approach him and talk things over as with a friend A medical officer such as this is a pearl of great price, and his value cannot be computed in terms of lives saved or tragedies averted The reverse holds true of doctors, however worthy and well-qualified, who are not interested in this particular problem

A doctor who is also an experienced and competent pilot, qualified to fly current operational aircraft, is of great value in work of this sort, because not only is he better fitted to appreciate the problems which are presented by virtue of his personal experience, but aircrew will pay more attention to his counsel on that account, and his advice and opinion on flying problems will be more readily sought

Where possible the medical officer best acquainted with the case should deal with it The importance of this fact has been stressed before, because, except in cases of exceptional difficulty, the man who knows the patient well is better qualified to judge than a person of greater professional experience who is not conversant with the day-to-day life of the patient It may, of course, be necessary at a later date to hand over to the psychiatric specialist, to whom the opinion of this medical officer will be of great value, but in many cases such a course will not be necessary

**2. Speed of Action.**—For such cases one cannot delay, something must be done at once, and should not be put off even until the next day, because in the intervening period the person concerned may well be subject to a severe strain which turns out

to be the precipitating factor in a crisis. This does not mean that a decision has to be hastily or sketchily decided upon, but once the issue is clear, immediate action should be taken to remove the person from flying, alter his duties, have the flying programme changed, or take whatever steps the medical officer may consider necessary. This entails a very confidential relationship between the medical officer and the executive, because the removal of one member of an aircrew from flying duties, and his substitution, so that the programme may be carried out without hindrance, is not an easy matter. If, however, a medical officer has built up the confidence of the executive in his professional opinion, there should be no trouble in this respect. In the early stages, treatment should be conducted with as much informality as possible. Above all, the patient should feel that something is being done. It should involve frank discussion on both sides, a real attempt to elucidate the underlying causes, a simple explanation of how these factors bring about certain psychological states, and a practical approach to the problems revealed. The lines of treatment must invoke, where possible, the common sense, co-operation, and goodwill of the person concerned.

**3. Elimination.**—Wherever possible, unsuitable cases should be eliminated by preselection, or during the training stage. If this is not done they should be removed as soon as symptoms manifest themselves. Psychological disorders are peculiarly contagious, and it is important that any cases removed from flying should be segregated from their colleagues as far as is practicable. In many cases where this was not possible, the presence of such a person undoubtedly had a bad effect on other aircrew members.

**4. Physical Fitness.**—A high standard of physical fitness for all aircrew personnel was at one time enjoined for purely physical reasons, but at a later stage it fell into disrepute when it was found that many people flew extremely well who were not models of athletic prowess. It has recently, however, been fully confirmed in practice that not only is a high standard of physical fitness desirable from the point of view of efficient performance of aircrew duties, but it is also important from the point of view of general morale of a squadron, and their potential resistance to the effects of flying stress. Lack of physical fitness is a predisposing factor in fatigue, which in its turn may produce psychological breakdown. Competitive games, organized physical training, and individual out-of-door activities such as swimming and golf, are all of value in this respect.

**5. Fatigue.**—Fatigue is the biggest single factor in the production of psychological breakdown, and every effort should be made

to eliminate it, as indicated in Chapter XXI The number of factors which contribute towards this condition are legion and a few only will be mentioned in passing, despite having been referred to before as having particular importance

Adequate, restful, undisturbed sleep is essential to all aircrew, and their quarters should be comfortable, properly heated and ventilated, and as quiet as possible A certain number of hours of rest should be laid down as a minimum and they should be encouraged to train themselves to sleep at peculiar times, and in the daylight, a matter which many of them find difficult, thereby losing valuable hours Leave should be properly spaced according to the operational requirements and be absolutely inviolable The psychological effect of the expectation of a period of leave is extremely stimulating to a tired member of aircrew, and nothing should be allowed to interfere with it The frustration and disappointment caused by uncertainty about leave, or repeated postponement, has a very bad effect on a person's mental condition If it is decided that sick leave is necessary it should be immediate, the patient should not be allowed to say "I will start to-morrow", but should be put to bed immediately and the necessary sick leave instituted at once If the patient is restless or cannot sleep, the barbiturate drugs are of great value An attempt should be made to see that the patient gets a minimum of ten hours' sleep for three or four nights Nembutal gr 3 nocte is usually adequate in such cases, but in severe cases a continuous narcosis with sodium amytal has proved beneficial The method is described in full in the section on treatment of fatigue in Chapter XXI and may be combined with psychotherapy at the same time If the condition is one occasioned by excessive strain due to abnormal conditions, such as a particularly heavy operational programme, or a person having to undertake duties not originally allotted to him, the situation can often be relieved by attention to these facts, and such decisions often require considerable firmness on the part of the medical officer concerned, when advising a hard-pressed operational executive

**6. Food and Comfort.**—Attention to aircrew meals both on the ground and in the air is of great importance They should be appetizing, well cooked, and served hot, and a conscientious medical officer will pay particular attention to supervision of this point It has been said that an army marches on its stomach, and it is also true that aircrew personnel fly on their abdominal organs Good food on return from a difficult flight, or at intermediate stages on a long trans-oceanic crossing, is a very important factor in warding off fatigue and assisting morale The comfort of aircrew

should not be neglected, and although an airfield is often a difficult place on which to provide this, every effort should be made to prevent a lax attitude by the authorities in this respect. Crews

of fatigue and lowered morale.

**7. Limit of Tour.**—This is as important as regularity of leave The limits of an operational tour will have to be determined by many factors, including the nature of the operations, average length of trips, and conditions under which operations are conducted Only by experience will a person be able to judge the optimum in this respect If, however, the limits set are too long, keen personnel will continue far beyond the limits of their strength, whereas less keen ones will have no stimulus to reach a certain specific goal, such as the completion of their tour of duty. In practice there is no doubt that the approaching end of an operational tour produces a beneficial stimulus to morale and efficiency which is quite noticeable

**8. Mixing of Aircrew.**—When a clear-cut distinction exists between commissioned and non-commissioned members of one crew, it is important for the maintenance of morale that adequate facilities are provided for the proper mixing of personnel This need not in any way interfere with discipline If a separation is observed which is leading to neglect of one section at the expense of the other, attention should be drawn to it

**9. Promotion.**—The medical officer should be a responsible adviser to the executive when consideration of promotion arises. The position of a leader in an operational squadron is one of vital importance, and if mistakes are made, they are difficult to rectify at a later stage, and may result in a period of prolonged trouble for the squadron as a whole. The question of leadership is discussed more fully elsewhere (Chapter XXXIII)

**10. Disposal.**—Aircrew with neuroses showing themselves during the first third of an operational tour are unlikely ever to give further useful service, and, other than in exceptional cases, should be removed from flying duties It will usually be found that they have considerable predisposition Those cases occurring in the second or middle third of a tour should be given some form of encouragement and psychological treatment to overcome their disability, and will in all probability, if properly handled, go on to

always those caused by fatigue, or excessive flying stress, and will, in a vast majority of cases, respond satisfactorily to an adequate period of rest. Prognosis in such cases is good

**11. Accidents.**—In practice it has been found that the system of getting a person to fly soon after a crash is a sound one, but it is only sound if, from that time onwards, flying continues regularly It is a recognized axiom among flying personnel that the more you fly the more you want to, the less you fly the less you want to, and this is particularly true after accidents A person who flies immediately after an accident, and then has two or three days without flying, is really no better off than if he had not flown at all, but if, where physical circumstances permit, it is possible to continue flying this should always be done In this connexion it is of great value for the medical officer to fly with the patient himself He can thus observe his reactions first-hand, and it also gives the patient added confidence in his own ability, which might have been shaken by the nature of the accident Sound restful sleep is essential after a crash, and if strict attention is paid to this, a person will subsequently wake up remarkably free from after-effects A restless, disturbed night, however, is a precursor of trouble later on Although discussion of the features surrounding an accident has been deprecated on many occasions, it is valuable if properly conducted Frank discussion, with admission of errors, or consideration of difficulties, together with an explanation and a reassurance, are often valuable in restoring a pilot's shaken self-confidence

## G. SUMMARY AND CONCLUSIONS

The problem of flying stress and its effect upon aircrew personnel operating under war conditions is one which by its very nature can only be examined from time to time, and continuous study of the subject is not possible Prior to this war little authentic information or considered opinion was available as a basis on which to work, and as a result errors were made, false clues were pursued, and sins of omission and commission in treatment performed There was little or no guide for a medical officer dealing with these problems in the early stages, and only the passage of time built up a sufficient number of cases for conclusions to be reached Conditions of warfare were constantly changing, and fresh circumstances were repeatedly arising which demanded a new approach to the situation The factors enumerated in the previous paragraphs on the subject are in many ways incomplete, and will doubtless be added to by writers at a later date, but they represent

a study of the problem from the non-specialist angle, the methods of investigation and approach being largely based on the recommendations of psychiatric specialists, aided by the experience and common-sense of medical officers carrying out the treatment

The conclusions reached in the overall problem of aircrew neurosis are that many cases can be prevented by careful avoidance of predisposing factors, by vigilant supervision, and instant action when the earliest signs of such disease are observed Encouraging results accrued from such treatment, and of those who were referred to psychiatrists 48 per cent returned to full flying duties and 60 per cent to some form of flying duty Cases can be cured only if radical efforts are made to eliminate the underlying causes of the trouble. Signs and symptoms are in many cases confusing and conflicting, and no rigid system of diagnosis, prognosis, and treatment can be laid down Each case must be judged on its merits, taking into account all the varied environmental factors in their correct proportion and perspective Infinite patience, tact, understanding, and conscientious application on the part of the medical officer, is a necessary adjunct to success. The results achieved, however, merit every confidence in the value of such work, and justify the belief that a great deal of psychiatric illness in aircrew can be prevented by approved methods

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## *CHAPTER XXXIII*

# MORALE

## *A* DEFINITION

MORALE is *a term generally understood, widely accepted, but* difficult to explain in simple language. It represents *l'esprit de corps* present in a group of people, their attitude towards adversity, their tenacity, their zeal, their optimism, their stamina, their outlook, it is indefinable, and at the same time patently obvious; its fluctuations can be clearly felt by any observer of human nature In an operational unit it is of pre-eminent importance, and it can be said without fear of contradiction, that on the morale of a squadron depends its success as a striking force, its efficiency on the ground and in the air, the general fitness rate among the crews, and the loss-rate due to enemy action and accidents In aircrew it can best be expressed as a sense of quiet confidence and eagerness to carry out the task in hand It does not mean facile optimism, the avoidance of unpleasant facts, an exaggerated enthusiasm, or a stimulated keenness and interest It is subject to wide fluctuations depending on a variety of conditions, some of which are outlined below

## *B* FACTORS INFLUENCING MORALE

**1. Leadership.**—This is the keystone on which good morale is built; send a good leader to a squadron of low morale and in a short space of time he will build it up; put a bad leader into a squadron with high morale and, given time, the standard will deteriorate On many occasions the success or failure of an identical body of men will be directly influenced by the quality of leadership, whether it be the captain of an aircraft or the commander of a flight or squadron. Leadership is vital, and the qualities of a good leader have been reiterated many times in different text-books, but where an operational air squadron is concerned there are particular factors which apply. He is always present, whether it be at times of crisis, sport, perplexity, or jubilation A leader who, at any time, dissociates himself from the men working under him very quickly loses his grip. Personal example is of

great importance, is the touchstone of success, and marks a man out immediately as a leader or otherwise His courage should be of the highest order, his decisions wise and prompt, his discipline firm and fair, and his understanding of human nature above average His skill as a pilot is relatively unimportant, provided the personal qualities mentioned above are present and his operational skill is up to the required standard, many first-class squadron commanders were well below average in their piloting skill and technical ability Their powers of leadership, however, were outstanding, and completely eclipsed the other factors

A good leader will nurse the timid through a difficult period, encourage the depressed when results are not up to standard, will not hesitate to reprimand that which is inimical to good discipline, and will be ready with reward and praise where it is deserved It may be necessary for him to fly with a bad crew in order to bolster up their morale, or correct faults—a courageous and unpleasant task In operational work he will choose the hard and dangerous targets for himself with impartiality, he will fly in the bad weather as well as the good, he will use the unpopular aircraft, and take the doubtful navigator and air-gunner as his companions

A classical example of excellent leadership may be quoted in this connexion. A squadron had suffered from two indifferent commanders in succession, and as a result morale was on the wane, and operational efficiency at a low ebb At this point a new squadron commander of outstanding ability, courage, and powers of leadership was appointed One night, shortly after his arrival, when the squadron had been briefed for an extremely dangerous target, in bad weather, a telephone message was received from the outlying dispersal point, where an aircraft was standing, to the effect that a pilot felt unwell and could not take off. Whether the cause was organic or functional was a matter of opinion what was clear was that the success of the operation would be interfered with if one aircraft failed to take off with the others Without hesitation, with no preparation in the way of a meal, adequate briefing for the target, suitable clothing, or any other desirable preliminaries, the new squadron commander, without comment, handed over his duties to a subordinate, got straight into the aircraft, and was airborne within a few minutes He completed a successful sortie under difficult conditions, and was extremely exhausted on return, having had no food for many hours The effect, however, on the morale of that squadron was dramatic From that time onwards it never looked back, and progressively improved its standard of performance, its record of success becoming quite legendary.

**2. Success.**—Success is essential to high morale, and this fundamental truth has been proved time and time again in all fighting services. Success need not be continuous. Its effects will remain, and be of benefit for a considerable time, carrying a body of men through subsequent periods of failure and difficulties

**3. Comradeship.**—The value of comradeship lies in the support under difficulty that aircrew receive from one another, and this is particularly true on night operations. It is noticeable what distress is caused when the intercommunication system fails, and persons are unable to talk to one another over a long period of flying by night At time of stress when encountering hazards, the companionship of a well-mixed crew can achieve wonders

**4. Inactivity.**—Inactivity is the worst enemy of morale People who are not busily occupied find time to brood over difficulties and setbacks, and unless firm discipline and adequate training is employed to discount this, the results can be serious.

***5. Losses.**—The influence upon morale of losses is more variable* than was at one time imagined Thus a high proportion of losses do not necessarily lower morale, although on the other hand a low loss-rate elevates morale. If the morale, discipline, and leadership of a squadron is high enough, it will be unaffected by losses This has been a matter of recurring surprise to observers, but has been shown to be consistently true On one occasion, there were two neighbouring squadrons and on the same night one squadron lost a number of aircraft over an extremely difficult target, and the other squadron lost one aircraft due to pilot error on returning to this country. The squadron with the larger loss was almost unaffected, whereas in the case of the squadron with one loss, an immediate adverse effect upon morale was evident

**6. Living Conditions.**—If living conditions on the ground are bad, or men feel they are uncared for, and thought is not given to their welfare when off duty, their morale is bound to suffer The good squadron commander will always consider one of his primary tasks the institution of all the necessary measures to see that his men are well cared for, and their living conditions satisfactory

**7. Appreciation of Task.**—This is very important, and a squadron commander who underestimates the danger, severity, or difficulties of the task he is calling on his people to perform, is deliberately undermining their morale Exaggeration in either direction is bad, but leaders who achieve the best results are those who make an honest assessment of the task to be faced; the degree in which they get the support of the crews is proportionate to the belief those crews have in such views

**8. Physical Fitness and Training.**—Bodily health, by engendering a general feeling of well-being, is a minor, though important, factor in the maintenance of morale, and its importance should not be overlooked At one time it fell into disrepute owing to exaggerated claims for its importance, but its value is undoubted if judiciously applied The importance of training is repeated, to emphasize the important part it plays in the general well-being and high morale in any body of men

## C SUMMARY AND CONCLUSIONS

No text-book definition of morale adequately describes its implications, but anyone who has studied aircrew operations will realize what a vitally important part it plays in the success or otherwise of a squadron's performance It can vary through the widest possible limits. It can stand tremendous shocks when well established. It can be influenced by one man, or a variety of less obvious causes. Its definition is difficult, its influences profound, and a medical officer who is wedded to his task can be an influential factor in its maintenance, for he watches for any signs of deterioration, and institutes remedial action without delay

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## CHAPTER XXXIV

# ACCIDENTS

WHILE the primary function of a medical department in connexion with accidents is to render assistance to the injured, considerable help can be afforded by an inquiry into the physical and psychological factors which go to produce them

## *A.* PREDISPOSING CAUSES

A variety of factors may be quoted as playing their part in relation to the aetiology of flying accidents, some of which are indicated below

**1. Weather.**—Bad weather—at take-off, during the flight, or on return—is productive of many accidents. The least important usually is the weather at take-off, because in most cases aircraft can climb above it and quickly settle down to instrument flying. *During the flight it is not of great importance as far as actual* flying hazards are concerned, as modern aircraft will stand up to very hard buffetings without trouble. In this respect one serious factor encountered is that of icing, which, first by making all movable control surfaces difficult to operate, and secondly, by altering the aerofoil characteristics of an aircraft, produces dangerous flying conditions It is possible, however, to get through an icing area relatively quickly The importance of bad weather on a flight, however, lies in the greatly increased fatigue which is produced Controlling an aircraft in bad weather is physically very tiring for the pilot Continual bumps and movements are exhausting for the crew, and air sickness may be induced, which adds to the general state of fatigue. Its greatest importance, however, is in connexion with weather over base on return Here all the adverse factors apply. After a long flight the pilot may *be tired and not at his best, the fuel supply* may be running short, the structure of the aircraft, damaged by enemy action, may be failing, other aircraft in a similar condition may be endeavouring to land, and a state of tension exists, which is not conducive to clear and calm thinking Landing is a complicated and highly co-ordinated procedure, depending on visual, auditory, and other

aids, and where these are imperfect or lacking, the liability and risk of accident is greatly increased It is sad to reflect how many aircraft in wartime returned safely from missions over enemy territory, only for their crews to be killed within a short distance of the station on which they lived

2. **Fatigue.**—There is no doubt that fatigue, by slowing down a pilot's reactions, increases the liability to accidents, in particular those concerned with landing, though a well-disciplined pilot will often realize his limitations in this respect, and take more than ordinary care over a relatively simple operation, to ensure that his actions are up to normal standard One manifestation of fatigue, which is of major importance in accidents, is that of visual strain, in which a person's powers of convergence and accommodation are diminished In many cases examined, the common symptoms found were aching eyes, difficulty in judging distance, lacrimation, blepharospasm, and intermittent exophoria, as a result of which instruments were blurred and indistinct Examination of these cases a few days later, after the patient had been rested, revealed none of these symptoms present

3. **Opposition.**—There is little evidence to support a relationship between the amount of opposition encountered in battle and the incidence of accidents Apart from structural damage to the aircraft, *which is not being considered here, and the presence of* acute fatigue following extremely severe opposition, there appears to be no significant relationship

4. **Insufficient Training and Flying Experience.**—This is a common cause of accidents, but does not obtain very much in operational flying, as at that stage most pilots have considerable experience It can be observed, however, in pilots changing from one type of aircraft to another, and in these cases there is undoubtedly a considerable psychological element present, by reason of apprehension concerning the characteristics of a new and untried aircraft

5. **Physical.**—A review of accidents conducted by the United States in 1942 revealed that an appreciable percentage of accidents (over one-fifth) occurred with pilots who had some physical impairment or disability, but this has not been confirmed by investigations in this country. It is difficult to assess what degree of physical impairment is listed officially as a disability as far as flying is concerned

6. **Mental.**—It may appear to be a truism, but with a few exceptions it is interesting to note the relationship between intelligence, educational background, and the accident rate Records show that in those pilots who originally or subsequently attained a high educational standard, the accident rate tended to

be lower The necessary action required to control an aircraft can be acquired in two ways: first, by an intelligent appreciation of the theoretical and practical principles involved; secondly, by a parrot-like imitation of instructions received

In the first case it will be appreciated that if there is a complete understanding of these principles, when a situation arises beyond the pilot's control involving reasoned thought and application, the intelligent pilot will be able to meet it. On the other hand, the pilot who has learned to take certain action only by constant repetition and slavish imitation, will fail, even though the standard of flying under normal circumstances is not widely dissimilar Inquiries into a number of accidents have often revealed an unintelligent appreciation of simple facts, a knowledge of which would probably have avoided the accident altogether

*7.* **Psychological.**—Any factors tending to preoccupy a pilot's mind increase the liability to accident. Thus, in a number of cases investigated, the pilot admitted that for a short while preceding, his mind had been preoccupied with other matters not related to flying, usually domestic ones Acute worry over personal affairs often causes mental aberration for the immediate tasks in hand Temperament has been discussed elsewhere, and, while playing a large part, is very difficult to assess in terms of liability to accidents.

*8.* **Pilot Error.**—Although the majority of cases of accidents are classified as pilot error, there are a number of other factors to be considered, such as errors of ground crew, navigational errors, flight engineers' errors, and other non-predictable causes The pilot, however, is the person ultimately responsible for decisions which have to be made He is the person by whom the effects of fatigue are mostly felt, and analysis of all cases shows that the final action precipitating an accident is usually taken by him. There is no doubt that this fact is due in part to the greatly added strain that he has to carry due to his responsible position during the entire flight.

### *B.* PREDICTABILITY

It was thought in the early stages of the war that it would be easy to differentiate between the pilot who was going to have frequent accidents and the pilot who was not The clumsy 'ham-handed' pilot was thought to be the potential trouble-maker, whereas the highly skilled, polished flyer was thought to be much less of a liability Although fundamentally this is borne out in practice, there are innumerable examples which contradict the theory, and a wide analysis of all accidents shows that the least

accident-prone types are those who pursue the middle course, and whose outstanding characteristic is reliability Thus by many, stability under conditions of stress is considered to be of greater importance in avoiding accidents than technical flying ability The clumsy pilot is often well aware of his shortcomings, either by the recriminatory remarks of his companions, or by his own observations, and he consequently takes more than average care A modern aircraft will stand up to considerable abuse in this respect, and such a pilot will complete large numbers of flying hours without any trouble The highly skilled and polished pilot, however, lacks this quality, and may often attempt manœuvres which are within his powers, but which involve an element of hazard and risk, in which an unfortunate combination of unpredictable circumstances precipitates an accident, more accidents have been caused in this way than through slightly subnormal standards of piloting On the other hand, it must be remembered that a pilot such as this may compensate, by extricating himself from an otherwise difficult situation by a brilliant piece of flying The steady, unsensational, just-above-average pilot is far and away the least susceptible to accident rate He has no illusions about this superior skill, has no desire to demonstrate the superiority of his technique, and is sensibly conscious of his own and the aircraft's limitations There still remains one class which is the exasperation of all instructors, executives, and medical officers, and that is the erratic and unpredictable temperament—a person who shows flashes of brilliance coupled with extreme stupidity, and whose every flight may turn out to be a triumph or disaster. Were the man-power position to permit of it in war-time, such persons would be much better removed from flying duties, as they exert a difficult and unsettling influence on other aircrew. There is, of course, no place for them in commercial flying

An analysis of training results indicates that approximately one-third of those who fail to learn to fly do so because they are clumsy with hands or feet, while others fail chiefly for temperamental reasons At present there is no method of accurately assessing the temperamentally unfit, other than those extreme cases mentioned above where the personal or family history clearly indicates predisposition to psychological breakdown (Whittingham)

It is difficult, if not impossible, to predict with any degree of accuracy a person's proneness to accidents with the exception of the consistent, above-average, middle-class pilot to which reference has already been made With this class the issue is never in doubt, apart from unavoidable hazards, but in every other case a trained

observer can be wrong, time and time again, and any attempt to classify pilots in this way can only lead to discredit of the methods used in such an assessment, and efforts to ascertain, by psychiatric or psychological methods, those persons who are temperamentally ill-equipped for piloting duties have not on the whole justified their continuance, except perhaps in the case of the Cambridge cockpit test. In this test candidates are seated in a mock-up of a cockpit with all instruments and controls to hand, in which they are given a complicated 'flying' programme to carry out. Their reactions in the course of these duties are recorded graphically In an appreciable number of cases it was found that those candidates who obtained a high percentage of errors in the cockpit test, and therefore had been adversely reported on, were subsequently involved in accidents or incidents attributable to pilot error.

## C. TREATMENT AND PREVENTIVE MEASURES

Apart from steps taken by the executive to prevent air accidents, such as supervision of aircraft maintenance, airfield control, and accuracy of meteorological reports, there are certain medical considerations which play an important part in accident prevention, as shown below.

**Preventive.**—

1. *Preselection* —The question of preselection and pilot aptitude is dealt with in detail in another chapter, but it would obviously be unwise to select a person for piloting duties with a bad psychological background, or an unstable personality liable to break down under conditions of stress. Elimination of such personnel at an early stage will remove a potential source of future trouble.

2 *Physical Fitness* —The institution of periodic medical examinations of all aircrew will eliminate cases whereby a pilot attempts to carry out his duties when not physically fit. In cases of long flights, such as trans-oceanic or trans-continental ones, pre- and post-flight examinations are of value, not only to discover any incipient disability, but also to asses the effects of that particular flight on the physical efficiency of the aircrews who operate the service

3 *Flying Conditions and Avoidance of Fatigue* —The supervision of such matters as proper diet, facilities for resting in the aircraft, elimination of noise and vibration, control of ventilation, adequate oxygen supplies, and avoidance of glare, are all factors which, by reason of their direct relation to the onset of fatigue, are important to watch if accidents are to be avoided The condition of the

cabin atmosphere when pressurized must be carefully supervised, particularly with regard to humidity, temperature, rate of airflow, and recirculation of air. In connexion with fatigue, as has been emphasized elsewhere, conditions for aircrew at stops on the ground are just as important as, if not more so than, conditions in the air, and adequate facilities for undisturbed rest at such places should be insisted upon at all times

4 *Crew Compatibility*—An ill-matched crew may, by reason of incompatibility of temperament, increase the liability to aircrew error at times of emergency A well-knit team will not often make a mistake under stress, a disunited team may

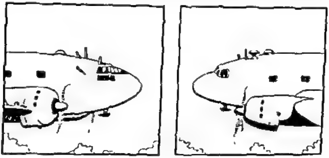
5. *Cockpit Design and Layout*—A uniformity of design and layout for cockpits of all aircraft, so that a pilot always knows instinctively the relative position of an instrument, and its method of adjustment, would constitute a valuable aid at times of emergency. The multiplicity of controls in modern aircraft and the increasing complexity of instruments designed to make flying safer, do not make quick and vital reference any easier, and increase the liability to error in an emergency A similar criticism exists with regard to controls, many of which have to be in the form of switches and levers It would not be safe for a pilot to look when operating them, any more than the driver of a car looks at his gear lever But if instead of one lever there are many, immediate tactile or spatial identification is vital To use the wrong one might precipitate an accident—to delay action in order to ensure correct application might be equally fatal

A solution would appear to be in the design of the handles themselves, and their careful positioning in the cockpit, so that immediately a pilot's hand came in contact with a lever he would be aware of its purpose As an example of this problem two very important levers are those operating the undercarriage and the flaps, and many accidents have been caused by the wrong one being used at a critical moment If a method were universally adopted, whereby undercarriage levers always had spade-type grips and flap levers bulbous grips, the possibility of an accident from such a cause would be considerably lessened Another important factor which is now receiving the care it deserves from designers of aircraft, is that of visibility for the pilot from the cockpit Unfortunately the best visibility is not always compatible with the best aerodynamic design, and the two considerations have to submit to a compromise best suited to both demands (*Fig* 131) The same factors in a different way apply to cockpit lighting, which is discussed in detail elsewhere (Chapter III, p 58) There are many other considerations in cockpit design and detail which are deserving of further

research, and the subject is one which merits close attention, an co-operation between designers, the medical profession, and ai crews themselves.

The presentation of information to the pilot by means of instru ments is very important in the prevention of accidents, and i undergoing intensive study at present. An aircraft is an extremel complicated piece of technical apparatus, and the informatio supplied is of a very diverse nature. It may concern his engines the weather, navigation, or other technical details

The objective in designing an instrument panel should be to present all the necessary information in the simplest and mos



easily recognizable form, in a manner which is not fatiguing or liable to errors of interpretation by day or night Over-simplification or over-complication must be avoided, and lighting, dial markings, distance from the pilot's eyes, and location on the instrument panel relevant to other indicators must be considered, so that economy of observation is obtained without loss of accuracy.

**Curative.**—The treatment and disposal of personnel who are subject to accidents is extremely difficult and to date a completely satisfactory solution has not been found. Reversion to a further period of training in some cases yields satisfactory results In a number of cases there is no apparent improvement and the only solution would appear to be to eliminate such persons from flying On the other hand, in those cases where the questioning reveals a particular factor which has influenced the condition, it can often be satisfactorily dealt with by frank discussion and intelligent appreciation of the condition by the subject himself, and no further trouble is experienced.

## D. SUMMARY AND CONCLUSIONS

There is no satisfactory method of determining whether or not an individual is going to be a liability so far as accidents are concerned, except in the cases of those obviously unsuited to flying, who are eliminated during the early training stages, due to absence of adaptability to flying conditions, or for other causes The only method which at present appears satisfactory, in individual cases, is to judge each one on its merits as observed under actual flying conditions In general, attention to all details of flying conditions as outlined in previous paragraphs is more important than is usually recognized, and the elimination, by such precautions, of any factors tending to produce fatigue, will contribute materially to a reduction in accident rates

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# PART V PREVENTIVE HEALTH

## CHAPTER XXXV

# EPIDEMIOLOGY AND AIR TRAVEL

## A THE PROBLEM

THE speed of modern air travel has resulted in problems concerning the transference of diseases which were never present in the older and slower forms of transport. In the case of travel by surface transport, the time taken in travelling from an endemic area to a non-endemic area was usually adequate for the manifestation of symptoms *en route*, and therefore appropriate action could be taken before passengers were allowed to disembark to ensure that no infected person introduced the disease to another country. With air travel this no longer applies; for example, England can now be reached from Egypt in thirteen hours by air, West Africa in a day, India in a day and a half, and China in four days. It is therefore apparent that local medical authorities must be actively concerned in ensuring that passengers on arrival or in transit by air are not incubating an infectious disease. As a result much reliance has to be placed on immunization by internationally approved methods, and insistence on the use of vaccines of known efficacy, the proof of having completed both of these requirements being the responsibility of the passenger concerned. Certificates of immunization have thus become an essential part of the formalities of air travel, and are likely to remain so for some time to come. Global maps of endemic areas are shown in APPENDIX III, and immunization certificates in Appendix IV.

## B INTERNATIONAL CONTROL

The carriage of infectious disease from one country to another is controlled by regulations drawn up by the International Convention for Aerial Navigation of 1944 (I C A N). This convention defines the procedure and methods to be adopted by the signatories for this purpose. These methods at present include immunization against the five diseases which are the subject of special measures—namely yellow fever, small-pox, plague,

typhus, and cholera—together with surveillance or quarantine of any suspected travellers, and quarantine of any proven cases or contacts In addition to these measures it will be necessary to ensure that aircraft, crew, and passengers are not carriers of such diseases, by the application of adequate sanitary measures, including methods for the destruction of mosquitoes and other disease vectors.

## C EFFECTIVE VALIDITY OF IMMUNIZATION PROCEDURES

The incubation periods for these diseases and the periods of validity of the certificates of immunization, agreed on internationally, are as indicated in the following tables :—

| Disease | Incubation Period | Period of Validity of Immunization Certificates |
|---|---|---|
| Yellow fever | 6 days (India 9 days) | 10 days to 4 years from date of inoculation |
| Small-pox | 14 days | 14 days to 3 years from date of vaccination |
| Cholera | 5 days | 6 months from date of completion of inoculation |
| Plague | 6 days | Not stated, usually 6 months from date of completion of inoculation |
| Typhus | 12 days | 1 year from date of completion of inoculation |

In spite of these internationally agreed periods of validity, foreign countries, very often at short notice, promulgate amended requirements. Instances of variations are recorded in the following table, which, although in operation at the time of writing, will most probably have been amended before this book reaches the reader, but are of value in illustrating the importance of always obtaining up-to-date information

Both limits of validity should be noted on making arrangements for immunization The consequences to a passenger who is not in possession of valid certificates may be a refusal to permit embarkation, or an enforced period of quarantine at the port of transit or disembarkation, or, in some cases, a refusal of permission to land

| Disease | ICAN Validity | Variations |
|---|---|---|
| Yellow fever | 10 days/4 years | Eritrea, French Somaliland } 6 days/4 years<br>Madagascar 15 days/2 yars |
| Small-pox | 14 days/3 years | Abyssinia, Iran } 12 days 1 year<br>Australia, Kuwait, Bahrein } 12 days/3 years<br>Borneo 10 days 3 years<br>Cyprus, New Zealand, South Africa, Philippines } 12 days/3 years<br>Portuguese East Africa —/5 years |
| Plague | None stated | Bahrein 6 days 1 year<br>Burma 6 days/6 months<br>Dutch East Indies 5 days 3 months<br>Cyprus 6 days/2 years<br>Iraq 10 days/3 months |
| Typhus | 1 year | India, Pakistan } 7 days/1 year<br>Palestine 12 days 1 year<br>Cyprus 9 days/6 months |
| Cholera | 6 days/6 months | Borneo 6 days/6 months<br>Iraq, Kuwait } 6 days/3 months<br>Italian Somaliland 5 days 5 months |

## *D.* HEALTH REGULATIONS PERTAINING TO DIFFERENT COUNTRIES

The extent of immunization which is necessary depends on the route flown The current regulations of each country transitted as well as those of the countries of departure and destination must be observed In certain cases authorities permit relaxation of these rules where a passenger is in transit through a country, but in such cases movements during the period of waiting are small, probably restricted to the airport In addition to the inoculations and vaccinations required by quarantine regulations, inoculation against the typhoid group is recommended to any person proceeding abroad and such others as may be indicated by an epidemic outbreak. It is understandable that countries which are free of a particular disease, but whose terrain and climatic conditions are particularly favourable for its spread, should exercise

stringent precautions to prevent the entry of carriers of such disease. Thus the regulations to preclude the importation of yellow fever into India are very strict, as are those imposed by Australia with regard to small-pox

Epidemiological information and quarantine requirements are collected by the International Commission of The World Health Organization at Geneva, and broadcast daily to the whole world A weekly Epidemiological Record is issued which provides information concerning the prevalence of pestilential disease throughout the world for National Health Services A monthly Statistical Supplement is also issued, giving tabular information concerning notifiable diseases and vital statistics.

The Ministry of Health in Great Britain issues a "Weekly Record of Infectious Diseases at Ports, or Other Localities at Home and Abroad" From these sources, and from information sent to Airline Corporations direct from overseas stations concerning local health regulations, it is possible to advise the immunization requirements for any particular journey.

## *E* HEALTH REGULATIONS ON ARRIVAL FROM A FOREIGN COUNTRY

Certain forms of certificate for the purpose of travel by air, as illustrated in Appendix IV, have been internationally agreed, and are recommended to be made available by all National Health Authorities Some Airline Companies print and issue these certificates on request to their passengers. It is an obligation on the part of all signatories to the convention to use these forms, or types of them, since any country is entitled to insist on their use, and may refuse to accept any other as valid, with resultant delay and inconvenience to the passenger It is important, therefore, that the certificates should be completed in all details, and officially certified by the approved authority.

Certain countries require passengers to give an account of their movements during the fourteen days prior to disembarkation. The purpose of such an inquiry is to establish their whereabouts during the period covering the longest incubation period, namely, that of small-pox Should they fall ill within the subsequent twenty-one days, they are instructed to report to the nearest doctor with a warning card issued to them on disembarkation, which states that the holder has recently arrived from another country, and may be suffering from a notifiable infectious disease At the same time the appropriate local Medical Officer of Health is informed by the Health Officials at the airport of disembarkation of

the names and addresses of any cases which have arrived Passengers who have been in contact with an infectious disease, or who are suspected of having contracted it, may be required to undergo medical inspection, followed by observation in a hospital or surveillance at their place of residence It may also be required that their persons and personal effects are cleansed or disinfected according to the circumstances

## F. CLINICAL DETAILS OF INOCULATIONS AND VACCINATIONS

Details of dosages for inoculation vary within small limits, some authorities regulating the dosage with the weight rather than the age, while the Public Health Laboratory Service issues a special diluted vaccine for inoculating children Furthermore, military authorities are not in complete agreement as to the optimum dosages in all cases.

Certain vaccines only are recognized internationally for immunization against yellow fever, and in this country they are prepared at the Wellcome Laboratories The vaccine must be kept at a temperature below 5° C., and the dosage made up for injection with sterile distilled water or normal saline

The clinical details given below satisfy the requirements of the World Health Organization, which is the recognized authority in such matters.

**1. Yellow Fever.**—One injection of 1000 to 2000 mouse units of anti-yellow-fever vaccine No lower age limit When protection against yellow fever and small-pox is required at the same time, special precautions are necessary They are outlined in detail on p 397

**2. Cholera.**—Two injections of anti-cholera vaccine with an interval of 7–10 days between each Not to be given under one year of age

| | |
|---|---|
| ADULTS (Male and Female) | |
| 1st dose | 0 5 c c |
| 2nd dose | 1 0 c c |
| CHILDREN (1–5 years) | |
| 1st dose | 0 1 c c |
| 2nd dose | 0 2 c c |
| (6–12 years) | |
| 1st dose | 0 2 c c |
| 2nd dose | 0 4 c c |
| (over 12 years) | |
| 1st dose | 0 5 c c |
| 2nd dose | 1 0 c c |

**3. Typhus.**—Two injections of anti-typhus vaccine with an interval of 7–10 days between each Only given in case of epidemics

or where it is a specific quarantine requirement by the country of destination or transit. Not to be given under one year of age.

| | |
|---|---|
| ADULTS (Male and Female) | |
| 1st dose | 1·0 c.c. |
| 2nd dose | 1·0 c.c. |
| CHILDREN (1–5 years) | |
| 1st dose | 0·2 c.c. |
| 2nd dose | 0·2 c.c. |
| (6–12 years) | |
| 1st dose | 0·4 c.c. |
| 2nd dose | 0·4 c.c. |
| (Over 12 years) | |
| 1st dose | 1·0 c.c. |
| 2nd dose | 1·0 c.c. |

**4. Plague.**—Two injections of anti-plague vaccine with an interval of 7–10 days between each. Only given in case of epidemics or where it is a specific quarantine requirement by the country of destination or transit. Not to be given under one year of age.

| | |
|---|---|
| ADULTS (Male and Female) | |
| 1st dose | 0·5 c.c. |
| 2nd dose | 1·0 c.c. |
| CHILDREN (1–5 years) | |
| 1st dose | 0·1 c.c. |
| 2nd dose | 0·2 c.c. |
| (6–12 years) | |
| 1st dose | 0·2 c.c. |
| 2nd dose | 0·4 c.c. |
| (Over 12 years) | |
| 1st dose | 0·5 c.c. |
| 2nd dose | 1·0 c.c. |

**5. Typhoid Group.**—Two injections of alcoholized anti-T.A.B. vaccine with an interval of not less than 10 days, preferably 3–4 weeks, between each. Is a recommendation only, and parents' sanction is necessary in the case of children. Not to be given under one year of age.

| | |
|---|---|
| ADULTS (Male) | |
| 1st dose | 0·25 c.c. |
| 2nd dose | 0·5 c.c. |
| ADULTS (Female) | |
| 1st dose | 0·2 c.c. |
| 2nd dose | 0·4 c.c. |
| CHILDREN (1–5 years) | |
| 1st dose | 0·1 c.c. |
| 2nd dose | 0·2 c.c. |
| (6–12 years) | |
| 1st dose | 0·2 c.c. |
| 2nd dose | 0·4 c.c. |
| (12–16 years) | |
| 1st dose | 0·2 c.c. |
| 2nd dose | 0·4 c.c. |
| (Over 16 years) | |
| 1st dose | 0·25 c.c. |
| 2nd dose | 0·5 c.c. |

**6. Small-pox.**—The method widely used is the multiple pressure method, and the application of lymph as recommended by the Public Health Authorities The results should be recorded as primary vaccinia, accelerated reaction, or reaction of immunity.

## G INTERPRETATION OF VACCINATION RESULTS

The interpretation of vaccination reactions may be described in the following way —

| Day of Vaccination | Reaction | | |
|---|---|---|---|
| | Primary Vaccinia | Accelerated (Vaccinoid) | Reaction of Immunity |
| 1 | | | Papule |
| 2 | | Papule | No vesicle |
| 3 | | Vesicle | Rapidly fades |
| 4 | Papule | Pustule | |
| 5 | Vesicle | Scab | |
| 8 | Pustule | Scab off | |
| 11 | Scab | | |
| 16–21 | Scab off | | |
| Immunity of individual before vaccination | Nil | Fair | Good |

## H SPECIAL PRECAUTIONS IN CERTAIN CIRCUMSTANCES

When, as is often the case with aircrew personnel or air travellers, vaccination against small-pox and inoculation against yellow fever are required as quickly as possible, there are certain optimum time limitations which should be observed in the interests of safety. The recommendations of the Ministry of Health in such cases are —

1 That yellow fever inoculation should precede primary vaccination against small-pox.

2 That there should be an interval of at least four days between yellow fever inoculation (when given first) and primary vaccination against small-pox (when given subsequently)

3 That if primary vaccination against small-pox is done first, there should be an interval of 21 days from the date of the vaccination before the yellow fever inoculation is given

4 That where there is evidence of previous successful vaccination against small-pox, yellow fever immunization and re-vaccination against small-pox may be carried out at the same session, but if time permits, yellow fever immunization should always precede re-vaccination by at least four days

## I. HEALTH MEASURES FOR AIRCRAFT

The structure of an aircraft renders it particularly liable to harbour disease vectors in many relatively inaccessible places such as *wings, cargo-holds, and fuselage.* Infection may be carried by rodents, mosquitoes, and other insects, as well as by food, water, cargo, or sewage, and special precautions are necessary in order to deal with such problems, quite apart from the routine measures for sterilization of water tanks and other containers, which are described in detail elsewhere

The specialized process for dealing with mosquitoes and other insects is known as disinsectization, and regulations require that it shall be applied to any aircraft whenever it arrives or departs from an airport in a yellow fever or malarial zone The procedure is carried out in the absence of passengers and crew, but with cargo *and fuel aboard*

The technique of the procedure is as follows The interior of the aircraft is sprayed with a pyrethrum aerosol containing not [illegible] not less than [illegible] n aerosol [illegible] 00 cu ft. of free air space All openings in the aircraft are kept tightly closed during the spraying, and for a period of not less than three minutes thereafter

When disinsectization has been carried out as described, a certificate to this effect, issued by the Quarantine Officer of the Ministry of Health at an airport in this country, will be accepted as proof of adequate protection for the particular aircraft

In the case of yellow fever, the Indian Government considers that an aircraft is 'suspect' if it arrives in India from the West, and '*infected*' *if* —

*a* It has a case of yellow fever on board,

*b* It has on board a non-immunized person who has been in a yellow fever area within nine days,

*c If either of the above conditions apply, and the aircraft* has not been disinsectized in accordance with the prescribed method

Regulations applying to the other diseases mentioned are described in detail in the regulations of the *International Sanitary* Convention

Confirmation that the measures required have been adequately carried out has to be presented to the authorities by the captain of the aircraft in a form of certificate, which is similar to a declaration of health at present in use for shipping

## 7 AIRCRAFT WATER SUPPLIES

Water is a frequent conveyor of disease, and it is therefore essential that an approved standardized routine should be adopted for the sanitary protection of supplies from source to consumer Sufficient quantities to last throughout the round flight of an aircraft cannot be carried in the tanks, and airlines are therefore faced with the problem of local overseas sources, and the maintenance of the necessary quality to ensure safety This involves incessant watchfulness over the cleansing of aircraft tanks, delivery bowsers, hosepipes, and portable containers, and chemical treatment in the aircraft itself of all water drawn off for consumption during flight This is achieved by removing all water tanks from aircraft at servicing bases at home for manual scouring and steaming, followed by strong chlorination of the cleansed interior, prior to filling with fresh potable water before initial take-off As an additional precaution, all water taken on at staging posts overseas should be charged during flight with a recognized sterilizing agent (such as chloramine T, halazone, etc ) before it is served, either for direct [illegible] quent flight

In order to achieve the best practical results, the active and intelligent co-operation of servicing engineers, catering supply officers, and stewards is essential Stewards and stewardesses should be instructed in the subject of water supplies, and engineering staffs and catering officers advised of the danger to health that might follow any inefficient or indifferent performance of their respective responsibilities in the matter of unclean vessels, germ-laden water, food material, and container flasks

Samples of water remaining in the tanks of aircraft arriving in the United Kingdom from abroad should be taken regularly and submitted to bacteriological examination A system of constant supervision should be established, and there should always be close liaison with the Local Port Health and Sanitary Authorities

## K MALARIA

This is a permanent problem in connexion with aircrew in any world-wide air transport organization, and it is important both from an economic as well as a health aspect that every precaution is taken to prevent flying personnel from becoming infected with the malarial parasite, or if infected, that the disease should be limited in extent and severity as much as possible

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In order to achieve the best practical results, the active and intelligent co-operation of servicing engineers, catering supply officers, and stewards is essential. Stewards and stewardesses should be instructed in the subject of water supplies, and engineering staffs and catering officers advised of the danger to health that might follow any inefficient or indifferent performance of their respective responsibilities in the matter of unclean vessels, germ-laden water, food material, and container flasks

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The specialized process for dealing with mosquitoes and other insects is known as disinsectization, and regulations require that it shall be applied to any aircraft whenever it arrives or departs from an airport in a yellow fever or malarial zone. The procedure is carried out in the absence of passengers and crew, but with cargo and fuel aboard

The technique of the procedure is as follows. The interior of the aircraft is sprayed with a pyrethrum aerosol containing not less than 0 4 per cent pyrethrins only, or containing not less than 0 2 per cent pyrethrins and 3 per cent DDT, applied from an aerosol dispenser for a period of not less than 15 seconds per 1000 cu ft. of free air space All openings in the aircraft are kept tightly closed during the spraying, and for a period of not less than three minutes thereafter

When disinsectization has been carried out as described, a certificate to this effect, issued by the Quarantine Officer of the Ministry of Health at an airport in this country, will be accepted as proof of adequate protection for the particular aircraft.

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Regulations applying to the other diseases mentioned are described in detail in the regulations of the International Sanitary Convention.

Confirmation that the measures required have been adequately carried out has to be presented to the authorities by the captain of the aircraft in a form of certificate, which is similar to a declaration of health at present in use for shipping.

before embarking on an air journey overseas in order to ensure that the current regulations are being complied with Non-compliance may result in embarrassing or irritating delays in other countries, which could have been avoided by attention to such details

All are agreed that a reduction in controls and certificates is desirable, but until such time as it can be ensured that such relaxation will not result in transmission of disease from endemic to non-endemic areas, such a step would be unwise and possibly disastrous.

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96, 209

Measures recommended to obtain these results include the following precautions, both general and specific.

1 The wearing of anti-mosquito clothing after dark in malarious areas. Such clothing includes slacks, long-sleeved shirts, buttoned up at cuffs and neck, and mosquito boots, if available.

2 The application of an insect repellent such as dimethyl-phallate every two hours to exposed parts such as the face, neck, hands, and ankles, except when under a mosquito net

3 The use of mosquito nets at night. Care should be taken to ensure that they are well tucked in under the mattress, and that they are free from holes It is wise to spray the interior with a DDT solution before retiring

4 Drug treatment consists of taking an appropriate antimalarial compound, Paludrine is very effective and is widely used by persons of experience, with good results

Among other advantages, it does not stain the skin or have any disturbing side-effects as is the case with other anti-malarial drugs, which means that aircrew are more inclined to use it prophylactically It is effective both as a prophylactic and as a means of attenuating the disease. The recommended dosage is one tablet daily, from the time of leaving the United Kingdom until seven days after return from, or through, a malarious area Used in this way it has been successful in reducing by a noticeable degree the incidence of sickness due to malaria among aircrew.

## L SUMMARY AND CONCLUSIONS

As stated at the beginning of this chapter, the speed of air transport has resulted in the institution of what at first sight might appear to be unnecessarily stringent and cumbersome regulations, but with the possibility of passengers and aircraft being in an endemic and non-endemic area on the same day it is impossible to ignore the results which relaxation of such health measures might bring about, and until there is more effective control of pestilential disease such restrictions will continue One suggestion which has been made is that airports which are largely used in transit might be specially controlled, so that all personnel working in them are immunized, the area itself completely epidemic free, and the buildings made to conform to stringent regulations, in order to eliminate the risk of infection of passengers in transit

It should also be noted that epidemiological conditions throughout the world are constantly changing and emergencies arise with little or no warning, so that regulations which are in force to-day may be changed to-morrow. It is therefore always wise to consult reputable publications or a recognized authority on the matter

# PART VI APPENDIXES

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## *APPENDIX I*

# I.C.A.O. MEDICAL REQUIREMENTS

## MEDICAL STANDARDS

### GENERAL

EACH candidate who presents himself for medical examination required for the grant or renewal of one of the licences, must furnish to the medical examiner a declaration, signed by himself, stating whether he has previously undergone such a medical examination and with what result A false

a member of the operating crew of a private aircraft ,

*b* Be deferred for two consecutive periods each of three months in the case of a member of the operating crew of an aircraft

practise legally as a physician

Medical examiners responsible for applying the critical standards for members of the operating crew must be aware of the practical conditions in which the personnel will have to fulfil their functions Each Member State shall designate, for the purpose of the medical examinations medical

ictice of

divided

into —

*Student Pilot*—

| | |
|---|---|
| *a* Physical Standard | No 3 |
| *b* Visual Standard | No 3 |
| *c* Colour Perception Standard | No 2 |
| *d* Hearing Standard | No 4* |

* A Private or Commercial Pilot who holds or wishes to hold an Instrument Rating will be required to reach the Hearing Standard appropriate for a Flight Radio Operator

## APPENDIX I

# I.C.A.O. MEDICAL REQUIREMENTS

## MEDICAL STANDARDS

### GENERAL

EACH candidate who presents himself for medical examination required [illegible]

a member of the operating crew of a private aircraft,

*b* Be deferred for two consecutive periods each of three months in the case of a member of the operating crew of an aircraft engaged in commercial operation—on condition that the person concerned obtains locally, in each case, a favourable medical certificate after having been examined by a medical man carrying out public functions, or simply admitted in that country to practise legally as a physician

Medical examiners responsible for applying the critical standards for members of the operating crew must be aware of the practical conditions in which the personnel will have to fulfil their functions Each Member State shall designate, for the purpose of the medical examinations medical examiners from among medical practitioners licensed in the practice of medicine by that State

Each Member State shall give its own methods of examination

The Medical Standards for the various types of licences are divided into —

[illegible]

| | | |
|---|---|---|
| *a* | Physical Standard | No 3 |
| *b* | Visual Standard | No 3 |
| *c* | Colour Perception Standard | No 2 |
| *d* | Hearing Standard | No 4* |

* A Private or Commercial Pilot who holds or wishes to hold, an Instrument Rating will be required to reach the Hearing Standard appropriate for a Flight Radio Operator

| | |
|---|---|
| *Private Pilot*— | |
| *a* Physical Standard | No 3 |
| *b* Visual Standard | No 3 |
| *c* Colour Perception Standard | No 2 |
| *d* Hearing Standard | No 4* |
| *Commercial Pilot*— | |
| *a* Physical Standard | No 2 |
| *b* Visual Standard | No 1 |
| *c* Colour Perception Standard | No 2 |
| *d* Hearing Standard | No 3* |
| *Senior Commercial Pilot*— | |
| *a* Physical Standard | No 2 |
| *b* Visual Standard | No 1 |
| *c* Colour Perception Standard | No 2 |
| *d* Hearing Standard | No 3* |
| *Airline Transport Pilot*— | |
| *a* Physical Standard | No 1 |
| *b* Visual Standard | No 1 |
| *c* Colour Perception Standard | No 1 |
| *d* Hearing Standard | No 1† |
| *Flight Navigator*— | |
| *a* Physical Standard | No 2 |
| *b* Visual Standard | No 2 |
| *c* Colour Perception Standard | No 2 |
| *d* Hearing Standard | No 3 |
| *Flight Engineer (or Flight Mechanic)*— | |
| *a* Physical Standard | No 2 |
| *b* Visual Standard | No 2 |
| *c* Colour Perception Standard | No 2 |
| *d* Hearing Standard | No 3 |
| *Flight Radio Operator*— | |
| *a* Physical Standard | No 2 |
| *b* Visual Standard | No 2 |
| *c* Colour Perception Standard | No. 2 |
| *d* Hearing Standard | No 1† |
| *Air Traffic Controller (Holding Zone Rating)*— | |
| *a* Physical Standard | No 3 |
| *b* Visual Standard | No 1 |
| *c* Colour Perception Standard | No 1 |
| *d* Hearing Standard | No 1† |
| *Air Traffic Controller (Area Rating)*— | |
| No requirement | |

## I. PHYSICAL REQUIREMENTS FOR LICENCES

### PHYSICAL STANDARD No 1.

The candidate must have the complete use of his four limbs, must be free from any active or latent, acute or chronic, medical or surgical disability or infection, that would entail any degree of functional incapacity which is considered likely to interfere with the safe handling of an aircraft at any altitude in the case of prolonged or difficult flight

The medical examination shall also be based on the following requirements of mental and physical fitness —

1 The candidate will be questioned concerning his family and personal history

2 *Examination of the Nervous System* —

*a* The examination of the nervous system of the candidate shall include a full inquiry into family and personal history The information obtained shall be given in a statement made and signed by the candidate He must be free from any history of morbid mental or nervous trouble The candidate must not present any mental or trophic impairment, pathological tremor, or presumptive evidence of latent epilepsy Motility, sensibility, tendinous, cutaneous, and pupillary reflexes, co-ordination of movements and cerebellar functions must be normal An exception may be made for local peripheral trouble due to accidental section of a nerve branch

*b* Injuries of the head will be dealt with as follows —

i Cases of simple concussion or simple fracture of the skull without associated intracranial damage will entail temporary unfitness for a period of not less than two months from the date of the concussion or fracture After the candidate has resumed his duties, his licence will be rendered valid only for successive periods of two months, until the after-effects no longer appear liable to produce a sudden incapacity in flight

ii In the case of severe intracranial injuries, the presence of local lesion of the brain will entail permanent rejection Any trepanning with loss of the bony substance involving the two tables of the cranial vault will entail rejection The same will apply in case of lesion of the dura mater, even after a bone-graft

*c* Any syphilis, past or present, affecting the central nervous system, or its blood-vessels or its membranes will entail the permanent rejection of the candidate Any presumed nervous syphilis will entail rejection, unless the non-existence of such an impairment is proved by an examination of the blood and an examination of the cerebrospinal fluid, made with the consent of the candidate

3 *General Surgical Examination* —

*a* The candidate must neither suffer from any wound or injury, nor

graphic examination/

*c* Any anatomical lesion in the walls of any part whatever of the digestive tract, and stricture of its calibre, any calculus or foreign body, any peritoneal lesion, established by clinical or laboratory examinations, will entail rejection Exceptions may be made for spasmodic strictures not accompanied by other troubles and for ptoses compensated for by a good abdominal musculature Any candidate who has undergone a surgical operation on the biliary passages or the digestive tract except for appendicitis, involving a total or partial excision or a diversion of any of these

operation certifies that no immediate or future after-effects are to be feared

only if they afford indication of the existence of a calculus, tumour, or lesion involving a persistent impairment of the functioning of these organs

4 *General Medical Examination* —

*a* The candidate must not suffer from any disease or disability which renders him liable suddenly to become incompetent in the management of aircraft His muscular power must be adequate for the handling of the types of aeroplanes he will have to pilot or the apparatus he is to use

*b* The heart must be normal, with normal function, and only respiratory arrhythmia, increase of pulse-rate from excitement or exercise, and a general slow pulse not associated with auriculoventricular dissociation will be allowed

*c* The candidate must not have any signs of aneurysm of the large arterial trunks

*d* The candidate must not suffer from any acute disability of the lungs, nor possess any cicatricial lesion of the lungs, and must be free from tuberculosis capable of being diagnosed by the usual clinical methods and, in the case of examinations for original acceptances by radioscopy, from disease of the tracheobronchial glands and from pulmonary emphysema, even if slight

*e* However, with regard to the maintenance of efficiency of the pilot, pulmonary emphysema will entail rejection only when marked

*f* In addition, each examination shall include a radiographic record in doubtful clinical cases

*g* When the examination of the spleen and of the ganglionic tracts

size The urine must not contain any pathological element Affections of the urinary passages and of the genital organs, even blennorrhœa, may entail temporary unfitness, an exception being allowed as regards the maintenance of efficiency in the case of tuberculous orchi-epididymitis in its mild and localized form

*i* The cases of candidates of the female sex who have undergone

a presumption of dysenteric infections shall entail rejection, unless the medical examiner considers that the clinical phenomena have disappeared.

5 *Eye Examination* —

*a* The candidate must have —

i No active pathological process, acute or chronic, of the internal ear or middle-ear cleft

ii *No unhealed* (unclosed) perforation or perforations of the tympanic membrane

iii No obstruction of the Eustachian tubes

iv No disturbances of the vestibular apparatus

*b* The details of the hearing standards shall be as set out in "Hearing Requirements for Licences"

7 *Nose, Throat, and Mouth Examination* —

The candidate must possess free nasal and tubal air entry on both sides and must have neither serious malformation nor serious, acute or chronic, affection of the buccal cavity or upper respiratory tract

## PHYSICAL STANDARD No. 2

The medical examination shall be based on the following requirements of mental and physical fitness —

1 The candidate must have a good family and personal history with particular reference to nervous stability Information as to this history must be given in a statement made and signed by the candidate

2. *Examination of the Nervous System* —

*a* The candidate must be free from any congenital or acquired disability of the nervous system causing such degree of functional incapacity as is considered likely to interfere, in the case of piloting, with the safe handling of an aircraft at any altitude even in the case of prolonged or difficult flight or, in the case of air work other than piloting, with the efficient performance of the duties for which a licence is being sought

*b* Injuries of the head will be dealt with as follows —

i Cases of simple concussion or simple fracture of the skull, without associated intracranial damage will entail temporary unfitness for a period of not less than two months from the date of concussion or fracture After the candidate has resumed his duties, his licence may be rendered valid only for a reduced period, or periods, until the after-effects no longer appear liable to produce a sudden incapacity during flight

ii Severe intracranial injuries, the presence of local lesion of the brain, trepanning with loss of bony substance involving the two tables of the cranial vault, or a lesion of the dura mater will entail permanent rejection

*c* Any presumed nervous syphilis will require to be investigated by an examination of the blood and an examination of the cerebrospinal fluid, made with the consent of the candidate

3 *General Surgical Examination* —

*a* The candidate must neither suffer from any wound or injury, nor [illegible]

sought

*b*. When palpation of the abdomen reveals any swelling or distinct pain, the abdominal examination must be completed by a radioscopic and [illegible]

by a good abdominal musculature Any candidate who has undergone a surgical operation on the biliary passages or the digestive tract, except for [illegible]

made by a surgeon, having knowledge of the nature of the disease which necessitated the operation, certifies that no immediate or future after-effects are to be feared

*c* Diseases of the liver (including those of the biliary passages) and of the pancreas will, in cases where it is deemed necessary, be verified by laboratory and other examination, particularly by radiography as well as by an examination of the blood and of the urine, and will entail rejection only if they afford indication of the existence of a calculus, tumour, or lesion involving a persistent impairment of the function of these organs

4 *General Medical Examination* —

*a* The candidate must not suffer from any disease or disability which renders him liable suddenly to become incompetent in the performance of his duties He must have no organic cardiac lesion His lungs must be in a state to withstand the effects of altitude He must be free from kidney d

*b* The

gynæcolc

Any pre

pregnanc

a candidate of the female sex will be allowed to resume her duties only after having undergone a new medical examination,

5 *Eye Examination* —

*a* The candidate must present no active or chronic pathological condition of either eye or adnexa which might interfere with its proper function The details of the visual standards for candidates for licences shall be as set out in " Visual Requirements for Licences " and those of the colour perception standards as set out in " Colour Perception Requirements for Licences "

6 *Ear Examination* —

*a* The candidate must have —

i No active pathological process, acute or chronic, of the internal ear or middle-ear cleft

ii No unhealed (unclosed) perforation or perforations of the tympanic membrane

iii No obstruction of the Eustachian tubes.

iv No disturbances of the vestibular apparatus

*b* The details of the hearing standards shall be as set out in " Hearing Requirements for Licences "

7 *Nose, Throat, and Mouth Examination* —

The candidate must possess free nasal and tubal air entry on both sides and must have neither serious malformation nor serious, acute or chronic, affection of the buccal cavity or upper respiratory tract

## PHYSICAL STANDARD No. 3

The medical examination shall be based on the following requirements of mental and physical fitness

1 *The candidate must have a good family and personal history with particular reference to nervous stability* Information as to this history must be given in a statement made and signed by the candidate

2 *Examination of the Nervous System* —

*a* The candidate must be free from any congenital or acquired dis- ... incapacity ... rcraft ... , nor ... enital ... dling of the aircraft under ordinary conditions

*b* When palpation of the abdomen reveals any swelling or distinct pain, the abdominal examination must be completed by the *radioscopic* and radiographic examination

*c* Any candidate who has undergone a surgical operation on the biliary passages or the digestive tract, except for appendicitis, involving a total or partial excision or a diversion of any of these organs, shall be declared unfit unless a period of two years has elapsed since the surgical operation and the effects of the operation are not now deemed liable to cause sudden incapacity in the air, or an attestation made by a surgeon, having knowledge of the nature of the disease which necessitated the operation, certifies that no immediate or future after-effects are to be feared

[illegible]

disease and must not present any clinical signs of syphilis

*b* The cases of candidates of the female sex who have undergone gynæcological or other surgical operations will be considered individually Any presumed pregnancy will entail rejection until, at least, after the pregnancy has been terminated

5 *Eye Examination* —

*a* The candidate must present no active or chronic pathological condition of either eye or adnexa which might interfere with its proper function The details of the visual standards for candidates for licences shall be as set out in " Visual Requirements for Licences " and those of [illegible] " Colour Perception Require-

[illegible] chronic, of the internal

[illegible] or perforations of the

[illegible] " Hearing

[illegible] y on both

[illegible] , acute or

[illegible] act

## II. VISUAL REQUIREMENTS FOR LICENCES

The measurement of the visual acuity will be made by means of a series of optotypes of Landholt, or similar optotypes, illuminated at not less than twelve lux and not more than twenty lux, and placed at a distance of 20 ft (6 metres) from the candidate, or 17 ft (5 metres) as appropriate to the method of testing

### VISUAL STANDARD No 1

1 The candidate must have —

*a* A visual acuity of at least 20/30 (6/9, 7) in each eye separately, [illegible] r both eyes is [illegible] 3) and can be [illegible] the candidate [illegible] e worn while

*b* In the case of application for an original licence, not more than + 2 [illegible]

*c* [illegible] na in either eye

*d* [illegible] na

*e* [illegible]

*f* An accommodation of at least V = 1 00 at 12 in (30 cm) with each eye separately without the use of correcting lenses Where the candidate is over forty years of age, correcting glasses may be used to provide the same character of near vision, if he already holds a licence.

*g* Normal visual fields

### VISUAL STANDARD No. 2

1. The candidate must have —

*a* A visual acuity of at least 20/40 (6/12, 5) in each eye separately, without correction, provided that if the vision in either or both eyes is poorer than 20 40 (6/12, 5) but not poorer than 20 80 (6/24, 25) and can be brought up to 20/20 (6/6, 1) or better in each eye by glasses, the candidate may be admitted, upon condition that correcting glasses be worn while exercising the privileges of licence

*b* Normal fields of vision, due allowance being made, where errors of refraction exist, concerning those areas not covered by the correcting lenses.

### *VISUAL STANDARD No. 3*

1 The candidate must have —

*a* A visual acuity of at least 20/40 (6/12, 5) in each eye separately [illegible]

## III. COLOUR PERCEPTION REQUIREMENTS FOR LICENCES

### COLOUR PERCEPTION STANDARD No. 1

The candidate must have normal colour perception as tested by means of Ishihara plates or isochromatic plates

### COLOUR PERCEPTION STANDARD No. 2

The candidate must be able to distinguish easily signal red, signal green, and white

## IV. HEARING REQUIREMENTS FOR LICENCES

The measurement of the auditory acuity in the first three standards detailed below will be made by means of a standard pure-tone audiometer in a quiet room, that is, a room in which the intensity of the background noise is less than fifty decibels, as measured by a sound-level meter

## HEARING STANDARD No. 1

The candidate must not have a loss in either ear of more than twenty decibels at any one of the four frequencies, 512, 1024, 2048, and 4096 cycles per second.*

## HEARING STANDARD No. 2

The candidate must not have a loss in either ear of more than twenty decibels at any one of the three frequencies 512, 1024, and 2048 cycles per second.*

## HEARING STANDARD No. 3

The candidate must not have a loss in either ear of more than forty decibels at any one of the three frequencies 512, 1024, and 2048.*

## HEARING STANDARD No. 4

The candidate must be able to hear a conversational voice using both ears and standing with his back towards the examiner, at a distance of 8.2 ft. (2.5 metres) from the examiner.

* In several countries, owing to the lack of suitable equipment and facilities at the present time, the Competent Authority may be unable to arrange compliance with Hearing Standards Nos. 1, 2, and 3, as detailed above. In such countries the Competent Authority should, as an interim measure, set alternative means of testing which they are satisfied are the equivalent of those detailed.

## *APPENDIX II*

# TABLE OF AVERAGE BODY BUILD

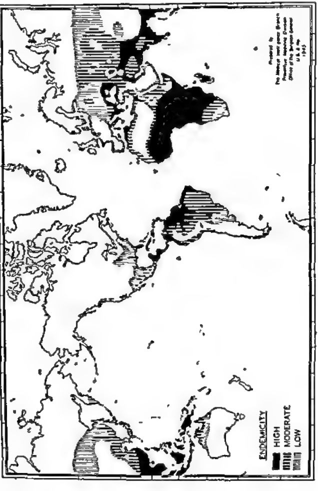
*The Average Body Build is the Weight shown in the Table for the Appropriate Age and Height*

| Age | Height in Inches | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 |
| | Weight in Lb. | | | | | | | | | | | |
| 17 | 117 | 120 | 124 | 127 | 130 | 134 | 137 | 141 | 145 | 149 | 153 | 157 |
| 18 | 118 | 121 | 125 | 128 | 131 | 135 | 139 | 143 | 146 | 151 | 155 | 159 |
| 19 | 119 | 123 | 126 | 129 | 133 | 137 | 140 | 144 | 148 | 152 | 156 | 160 |
| 20 | 121 | 124 | 127 | 131 | 134 | 138 | 142 | 145 | 149 | 153 | 157 | 161 |
| 21 | 122 | 125 | 129 | 132 | 135 | 139 | 143 | 146 | 151 | 155 | 158 | 163 |
| 22 | 123 | 126 | 130 | 133 | 137 | 140 | 144 | 148 | 152 | 156 | 160 | 164 |
| 23 | 124 | 127 | 131 | 134 | 138 | 141 | 145 | 149 | 153 | 157 | 161 | 165 |
| 24 | 125 | 128 | 132 | 135 | 139 | 142 | 146 | 150 | 154 | 158 | 162 | 166 |
| 25 | 126 | 129 | 133 | 136 | 140 | 143 | 147 | 151 | 155 | 159 | 163 | 168 |
| 26 | 127 | 130 | 134 | 137 | 141 | 144 | 148 | 152 | 156 | 160 | 164 | 169 |
| 27 | 128 | 131 | 135 | 138 | 141 | 145 | 149 | 152 | 157 | 161 | 165 | 170 |
| 28 | 129 | 132 | 136 | 139 | 142 | 146 | 149 | 153 | 158 | 162 | 166 | 171 |
| 29 | 130 | 133 | 137 | 140 | 143 | 147 | 150 | 154 | 159 | 163 | 167 | 172 |
| 30 | 131 | 134 | 137 | 141 | 144 | 148 | 151 | 155 | 159 | 164 | 168 | 173 |
| 31 | 131 | 135 | 138 | 141 | 145 | 149 | 152 | 156 | 160 | 165 | 169 | 174 |
| 32 | 132 | 135 | 139 | 142 | 145 | 150 | 153 | 156 | 161 | 166 | 170 | 175 |
| 33 | 132 | 136 | 139 | 143 | 146 | 150 | 153 | 157 | 162 | 166 | 171 | 176 |
| 34 | 133 | 136 | 140 | 143 | 147 | 151 | 154 | 158 | 163 | 167 | 172 | 177 |
| 35 | 133 | 137 | 141 | 144 | 148 | 152 | 155 | 158 | 163 | 168 | 173 | 178 |
| 36 | 134 | 137 | 141 | 144 | 148 | 152 | 156 | 159 | 164 | 169 | 174 | 179 |
| 37 | 134 | 138 | 142 | 145 | 149 | 153 | 156 | 160 | 165 | 170 | 175 | 180 |
| 38 | 135 | 138 | 142 | 146 | 150 | 154 | 157 | 161 | 166 | 171 | 176 | 180 |
| 39 | 135 | 139 | 143 | 146 | 150 | 154 | 158 | 162 | 167 | 171 | 176 | 181 |
| 40 | 136 | 139 | 143 | 147 | 151 | 155 | 159 | 163 | 168 | 172 | 177 | 182 |

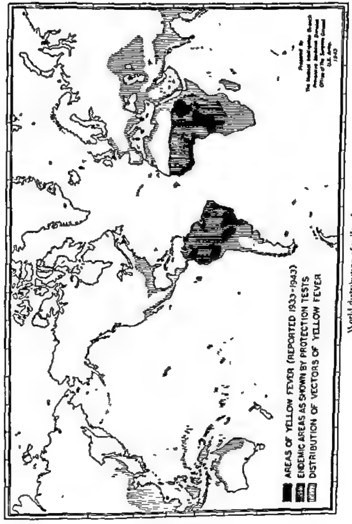
## *APPENDIX III*

## EPIDEMIOLOGICAL MAPS

*(From "Global Epidemiology", by courtesy of J B Lippincott Company)*



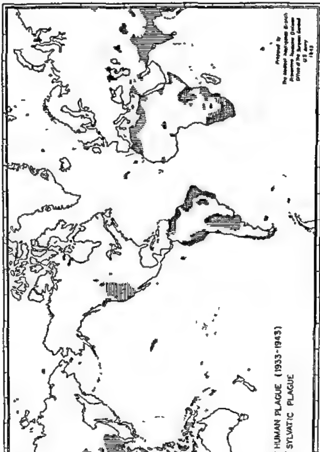

World distribution of malaria




World distribution of yellow fever

World distribution of typhus fever


World distribution of cholera




World distribution of plague

*APPENDIX IV*

# INTERNATIONAL CERTIFICATES OF INOCU AND VACCINATION

**International Certificate of Inoculation and Vaccination**

*In accordance with the International Sanitary Convention for Aerial Navigation, 1944*

★

THESE CERTIFICATES COMPLETED AS REQUIRED MUST BE HELD AVAILABLE AND SHOULD BE ATTACHED TO THE HOLDER'S PASSPORT

International inoculation certificate Cover

**International Certificate of Vaccination Against Smallpox**

THIS IS TO CERTIFY THAT

(Age          Sex          ) whose signature appears below, has this day been vaccinated by me against smallpox.

Origin and Batch No. of Vaccine

Official Stamp

Signature of Vaccinator

Official Position

Place

Signature of Person Vaccinated

Home Address

IMPORTANT: In the case of primary vaccination the person vaccinated should be warned to report to a medical practitioner between the 8th and 14th day in order that the result of the vaccination may be recorded on this certificate. In the case of revaccination the person should report within 48 hours for first inspection in order that any immune reaction which has developed may be recorded.

THIS IS TO CERTIFY that the above vaccination was inspected by me on the date(s) and with the result(s) shown hereunder

Date of Inspection          Result

Official Stamp

Signature of Doctor

Official Position          Date

Place

Use one of the following terms in stating the result viz — "Reaction of Immunity" "Accelerated Reaction (Vaccinoid)" "Typical primary vaccinia". A certificate of "No Reaction" will not be accepted.

Signature of Person Vaccinated

This certificate is not valid for more than 3 years from date of vaccination

International certificate of vaccination against small pox

### International Certificate of Inoculation Against Typhoid and Paratyphoid Fevers

THIS IS TO CERTIFY THAT

(Age Sex ) whose signature appears below was on the dates indicated inoculated against Typhoid and Paratyphoid Fevers (2 injections initially thereafter 1cc. annually if required)

| | MATERIAL | | | INOCULATING OFFICER | |
|---|---|---|---|---|---|
| DATE | ORIGIN | BATCH No AND TYPE | DOSE | SIGNATURE | OFFICIAL TITLE |
| | | | | | |
| | | | | | |

Signature of person inoculated

Official Stamp of Inoculating Officer

Home Address

Date

*This certificate is not valid for more than twelve months from date of inoculation*

International certificate of inoculation against the typhoid and paratyphoid fevers

### International Certificate of Inoculation Against Typhus Fever

THIS IS TO CERTIFY THAT

(Age Sex ) whose signature appears below was on the dates indicated inoculated against Typhus Fever (3 injections initially thereafter 1cc. annually if required).

| | MATERIAL | | INOCULATING OFFICER | |
|---|---|---|---|---|
| DATE | ORIGIN | BATCH No AND TYPE | SIGNATURE | OFFICIAL TITLE |
| | | | | |
| | | | | |

Signature of person inoculated

Official Stamp of Inoculating Officer

Home Address

Date

*This certificate is not valid for more than twelve months from date of inoculation*

International certificate of inoculation against typhus fever

## International Certificate of Inoculation Against Yellow Fever

THIS IS TO CERTIFY THAT_____ (Age ___ Sex ___ ) whose signature appears below has this day been inoculated against yellow fever (one injection)

Origin and Batch No of vaccine ___

Signature of inoculating officer

Official position ___ Place ___ Date ___

Signature of person inoculated ___

Home address ___

This certificate is not valid

(a) unless the vaccine and the method employed have been approved by UNRRA

(b) until 10 days after the date of the inoculation except in the case of persons re-inoculated within 4 years,

(c) for more than 4 years from the date of the last inoculation

| Official stamp of Inoculating Officer |
|---|

International certificate of inoculation against yellow fever

## International Certificate of Immunity Against Yellow Fever

THIS IS TO CERTIFY THAT ___

(Age ___ Sex ___ ) whose signature appears below is immune to yellow fever as the result of an attack of the disease This immunity has been demonstrated by the mouse protection test,

Date of bleeding ___ Place of bleeding ___

Name of laboratory performing test ___

Location of Laboratory ___

Date of Test ___ Result of Test ___

Signature of Laboratory Director

| Official Stamp of Laboratory |
|---|

Signature of person tested ___

Home Address ___

This certificate is not valid

(a) unless the Laboratory performing the blood test and the method employed have been approved by UNRRA.

(b) for more than ten years from the date of the blood test

International certificate of immunity against yellow fever

## International Certificate of Inoculation Against Cholera

THIS IS TO CERTIFY THAT ______________________

(Age ______ Sex ______ ) whose signature appears below was on the dates indicated inoculated against Cholera. (2 Injections)

| | MATERIAL | | INOCULATING OFFICER | |
|---|---|---|---|---|
| DATE | ORIGIN | BATCH No. AND TYPE | SIGNATURE | OFFICIAL TITLE |
| | | | | |
| | | | | |

______________________

Signature of person inoculated

| |
|---|
| Official Stamp of Inoculating Officer |

Home Address ______________________

Date

*This certificate is not valid for more than six months from date of inoculation*

International certificate of inoculation against cholera

## *Certificate of Other Inoculations*

| DATE | NATURE OF VACCINE | DOSE | ORIGIN | BATCH No | MEDICAL OFFICER | OFFICIAL POSITION |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Certificate of other inoculations

## *APPENDIX V*

# YELLOW FEVER INOCULATION CENTRES

## ENGLAND AND WALES

| | *Telephone* | *Times* |
|---|---|---|
| **Birmingham :** Regional Blood Transfusion Centre, 17, Highfield Road, Edgbaston, Birmingham, 15 | Edgbaston 1182 | Tuesday 2–3 p m |
| **Bournemouth :** Dr R Vaughan Facey, Burwood Glen, 13, St Stephen's Road, Bournemouth | Bournemouth 2815 | |
| **Bristol :** Regional Blood Transfusion Centre, Southmead Hospital, Bristol | Bristol 68021–3 | Tuesday 2–3 p m |
| **Cambridge :** Regional Blood Transfusion Centre, Brooklands Avenue, Cambridge | Cambridge 2536 | Monday 2 30–3 30 p m |
| **Cardiff :** Regional Blood Transfusion Centre 19, Newport Road, Cardiff | Cardiff 4521 | Monday 2 30–3 30 p m |
| **Leeds :** Regional Blood Transfusion Centre, Bridle Path, York Road, Seacroft, Leeds | Leeds 45091–2–3 | Friday 2–3 p m |
| **Liverpool :** Drs A Adams and R Seaton, School of Tropical Medicine, Pembroke Place, Liverpool, 3 | Royal 7611 | |
| Regional Blood Transfusion Centre, 102, Whitechapel, Liverpool, 1 | Royal 6314 | |
| **London :** The Wellcome Foundation, 183–193, Euston Road, N W 1 | Euston 4477 | Monday Wednesday and Friday only (by appointment) |
| **Manchester :** Regional Blood Transfusion Centre, Manchester Royal Infirmary, Oxford Road, Manchester, 13 | Ardwick 3832 | Tuesday, 2 30–3 30 p m |
| **Newcastle-on-Tyne :** Regional Blood Transfusion Centre, 78, Jesmond Road, Newcastle-on-Tyne, 2 | Jesmond 2992 Newcastle 21602 | Monday 2–3 p m |
| **Oxford :** Southern Regional Blood Supply Depot, Churchill Hospital, Headington, Oxford | Oxford 61316 | Monday 2–3 p m |
| **Plymouth :** Regional Blood Transfusion Sub-centre, City General Hospital, Plymouth | Plymouth 5021 | |

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|---|---|---|
| **Sheffield :** Dr P H Malone, Regional Blood Transfusion Centre, Northfield Road, Sheffield, 10 | Sheffield<br>63271 | |
| **Southampton :** Pathological Department, Royal South Hants and Southampton Hospital, Fanshaw Street, Southampton (*Inoculating Officer* Dr H H Gleave) | Southampton<br>76211 | Tuesday<br>2 30 p m |
| **Truro :** Pathological Department, Royal Cornwall Infirmary, Truro (Dr. F D M Hocking) | Truro<br>3029 | Tuesday<br>10–11 a m |

## SCOTLAND

| | | |
|---|---|---|
| **Aberdeen :** City Hospital Laboratory, City Hospital, Urquhart Road, Aberdeen | Aberdeen<br>2242<br>Ext. 11 | Thursday<br>3 p.m. (or by arrangement) |
| **Dundee :** University of St Andrews, Bacteriological Department, Medical School, 60, Small's Wynd, Dundee (*Inoculating Officers* Prof W. J Tulloch, Dr. J Brodie, Dr Haig McPherson, Dr. W. Shepherd) | Dundee<br>2144 | Monday<br>2 p m |
| **Edinburgh :** Bacteriological Department, Edinburgh Royal Infirmary, Lauriston Place, Edinburgh, 3 (*Bacteriologist in charge* Dr W R Logan) | Edinburgh<br>26031 | Mon and Wed<br>2.30–3 30 p.m |
| **Glasgow :** Public Health Clinic, 20, Cochrane Street, Glasgow, C 1 | Glasgow<br>Central 9600<br>Ext. 302 | Friday<br>2 30 p m |

## NORTHERN IRELAND

| | | |
|---|---|---|
| **Belfast :** Ministry of Health for Northern Ireland, Emergency Hospital, Musgrave Park, Balmoral, Belfast | Belfast<br>67693 | By arrangement with Medical Superintendent |

## CHANNEL ISLANDS

**Jersey :** Dr R N McKinstry, Public Health Office, St Helier, Jersey

**Guernsey :** Dr Rowan Revell, Health Dept, Lukis House, Guernsey

## EIRE

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|---|---|---|
| **Dublin :** Prof J W Bigger, Trinity College, Dublin<br>Dr. Patrick Meenan, Dept of Pathology, St Vincent's Hospital, Dublin | Dublin<br>62467 | |

# INDEX

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